EARTH'S FUTURE FORETOLD

What will our planet be like in 2100?

NewScientist

WEEKLY 5 October 2013

THE TRUE DAWN

Civilisation is older and more mysterious than we thought

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TAKE YOUR DATA BACK!
Now you can decide who sees what

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Time to rethink the early universe

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Kevin Maloney/Aurora/Getty

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The world is in our hands

The greatest source of climate uncertainty is political, not scientific

THE latest scientific report from the UN Intergovernmental Panel on Climate Change, published last week, was received almost with a shrug. There were no real showstoppers (no surprise, as most of the report had been leaked in advance). Minds were not changed. Battle lines did not budge. Denialists tried to rubbish the report but found themselves preaching only to the converted.

Perhaps the juiciest morsel was the IPCC's acceptance that warming has slowed since 1998 (see page 6). Even this has been widely studied and debated elsewhere; the IPCC simply reiterated that the change can be explained as part of the complex interactions between natural and human-made climate effects, with the big picture unchanged. The report is the product of painstaking consensus-building; it is inevitably not cutting-edge.

That is not to say the science is "settled". Science never is. Many uncertainties and complexities remain to be understood, but the chances that we will discover that we have got the big picture wrong are diminishing day by day. The work of climate scientists is now to fill in ever-finer details. So why are we still so uncertain what the future holds?

"The chances of discovering that we have got the big picture wrong are diminishing day by day"

The greatest source of uncertainty is not science, but society: the IPCC's declaration that the world will warm by anywhere between 0.3 and 4.8 °C reflects social and political uncertainties, not scientific ones. Climate scientists study the climate. They cannot tell us how much money will be invested in green energy R&D, whether fertility rates will go up or down, whether we will dig up all the remaining fossil fuels and burn them, or the outcomes of numerous other decisions that affect the atmosphere – though they can tell us what will probably happen if we do or don't take them (see page 8).

And so attention must now turn to the next two IPCC reports. The first of these, due out in March 2014, will cover impacts, adaptation and vulnerability; the second, out the following month, will cover mitigation.

As yet there are no leaks from these reports. They are likely to develop the theme that the future is still in our hands. We can choose to limit warming, or continue our carbon bender and take our chances in a world that is around 5 °C hotter. It's up to us. ■

Time to get personal over data

IT IS one of the biggest scandals of the past decade, and yet ongoing revelations about surveillance by the US National Security Agency have yet to fundamentally affect the way we choose to handle our personal data. Search engines that do not log user searches as Google does (such as DuckDuckGo) have seen a surge in traffic. But they still handle only a tiny proportion of web searches.

Why don't people seem to care? One important reason is that very few of us really understand, let alone control, the vast, intangible and invisible data trail we leave behind as we navigate the digital world. Perversely, internet companies and government agencies often understand what we're giving up better than we do.

Now technical fixes are starting to arrive to help us gain control over this trail. OpenPDS, for example, is a repository that alerts consumers to data requests from companies or intelligence agencies (see page 20).

Such solutions are helpful to those who are privacy-conscious and tech-savvy enough to use them. Even if they become easy to use, however, people may still consider that the exchange of data for services such as social media and email is a good deal. But do the users of these services really understand what they have given up? Consumers have largely sleepwalked into giving their data away. Perhaps the status quo is OK, but it has not yet been subject to a proper public debate.

Netizens might become more interested in that debate if the value of their data was more widely appreciated. It is a valuable resource – and not just to advertisers, snoops and spooks. The data can be used to improve public services such as transport, and promises to transform the social sciences with an unprecedented flood of information about how people go about their daily lives.

One of the obstacles in running these analyses is gathering the data itself, because it is jealously guarded by the communications companies that provide us with services. Even if we don't really care about the privacy of our personal data, we should still care who owns it. ■

Climate science tweaked

TELL us something we don't know. The latest report from the UN's Intergovernmental Panel on Climate Change (IPCC), published last week, is more confident than ever that most of the warming of the past 60 years is humanity's fault. The authors are now 95 per cent certain, up from 90 per cent in 2007. But there are some interesting new twists. The worst scenarios, for example, are looking less likely than they were a few years ago. And the IPCC admits for the first time that warming has slowed since 1998. This was not evident when the last report was compiled.

The lull may be a short-term blip. Perhaps the oceans are temporarily taking up more heat from the air, says Myles Allen of the University of Oxford. Solar cycles and the shading effect of smoke may also be involved.

Thanks to the slowdown, estimates of future warming are a bit lower.

But don't get too comfortable. The IPCC has almost doubled its estimate of sea level rise by the end of the century, to as much as 1 metre. Worse scenarios of 2 metres now seem unlikely, unless the Antarctic ice sheets do something unexpected. "If anything scary happens it will be in Antarctica," says Tony Payne of the University of Bristol, UK.

Clouds are also a menace. In 2007, it was uncertain whether clouds cooled or warmed the planet overall. "We now believe that they are a positive feedback on temperature," says Piers Forster of the University of Leeds, UK. "Their warming effect will intensify with global warming."

ADAM PASS/PLAINPICTURE

A warming blanket for the planet

1000-world trouble

FROM a grand to a millennium, 1000 is an important milestone no matter what you are counting. But as astronomers close in on the discovery of 1000 exoplanets, deciding when to award the title is proving troublesome.

For one thing, there are several exoplanet catalogues and each uses different criteria to decide when a planet has been spotted. As *New Scientist* went to press, the Extrasolar Planets Encyclopaedia, run by Jean Schneider of the Paris

"As astronomers close in on the discovery of 1000 exoplanets, when to award the title isn't clear"

Observatory in France, listed 990 worlds: Schneider expects 10 more within a few weeks. But other exoplanet databases were coming up lower, including NASA's own, which had just 906.

One reason for the difference is that Schneider adds planets when confirmation of their existence is presented at conferences, while NASA only accepts those announced in a journal. The latter takes longer. NASA also updates its list less frequently.

Lists aside, another problem is that no one can quite agree on the exact definition of a planet. This isn't the problem that befell Pluto, considered the smallest planet in our solar system until 2006, when it was demoted to a dwarf planet. It's actually the opposite – it's not clear how to distinguish planets at the larger end of the spectrum from failed stars called brown dwarfs. As a result, some ultra-heavy planets in catalogues today may eventually be removed.

Another wrinkle is that even confirmed exoplanets, spotted multiple times, can turn out to be tricks of the data. So far Schneider has deleted around 10 of these from his catalogue – but more could emerge.

Astronomers are keen to find a way through all this and mark the 1000th exoplanet. Whatever happens, it's a problem Schneider didn't imagine worrying about in 1992 when the first two exoplanets were glimpsed. "At the time we could not hope to have so many planets 20 years later."

Cyber attack squad

WELL, they do say attack is the best form of defence. The UK will launch cyberattacks, not just defend against incoming threats, defence secretary Philip Hammond announced this week.

The UK Ministry of Defence's £500 million plan is to create a military unit – the Joint Cyber Reserve – that will be staffed by hundreds of reservists, including experts leaving the armed forces and people "with no previous military experience" who have stellar computing skills.

"Every other nation state is now considering offensive as well as defensive cyber operations as part of their strategy, so it is about time," says Jay Abbott of Cyber Security Challenge UK, an annual competition to spot new talent.

But attacks must be carefully considered, he warns. The Stuxnet virus, for example, was reprogrammed after it was launched by the US in 2010 to take out Iran's nuclear reactors. "It's a bit like a missile. Once you've fired it you don't get to protect it."

Al-Shabaab's poaching links

TIME for a war on poaching? Hillary Clinton unveiled an $80 million plan last week by conservation groups and African governments to combat elephant poaching.

Announcing the plan, Clinton highlighted that money from wildlife crime may be helping to fund terrorist groups, such as the al-Shabaab group that attacked the Westgate shopping mall in Kenya two weeks ago.

The money will go towards scaling up anti-poaching activities, targeting supply lines and traffickers, and reducing demand for ivory in major markets, mostly in east Asia.

"Part of al-Shabaab's funding has been, and is still, from ivory," says Andrea Crosta of the Elephant Action League, an NGO in California. Between 2011 and 2012, he led an undercover investigation of poaching in Kenya. Poachers and brokers said they were increasingly selling to al-Shabaab, which sells the ivory on at a huge mark-up.

Reusable rockets

THE nascent commercial space-flight industry experienced something old and something new on 29 September.

One company, Orbital Sciences

"The rocket broke up on impact, but it wasn't all bad news: SpaceX now knows how to bring others home"

of Dulles, Virginia, docked a craft with, and delivered cargo to, the International Space Station (ISS). It is only the second commercial entity to do this, but it is a capability that government agencies have long had.

Meanwhile, SpaceX of California tested reusable rocket technology for launches. Their rocket broke up on impact rather than making the planned soft landing. But it wasn't all bad news: the reasons for the failure have been studied, prompting SpaceX founder Elon Musk to suggest they now know how to bring the rocket home safely.

For Orbital, the docking of its Cygnus cargo drone with the ISS was a relief. It had been delayed a week owing to a GPS data format mix-up that required a software patch. The successful docking should inject some healthy competition into the market to deliver cargo to the ISS – previously SpaceX was the only commercial entity offering the service.

THOMAS MUKOYA/REUTERS

White gold

AP PHOTO/M. SPENCER GREEN

Now on enforced holiday

US shuts down

HAPPY birthday NASA – now have an enforced holiday without pay.

Most of the agency's 18,000 employees were not in the office to celebrate its 55th birthday on Tuesday, as a result of the US federal government shutdown. They are just a small proportion of roughly 800,000 "non-essential" government workers, including many key scientific and medical providers, who

"Fewer than 600 of NASA's 18,000 staff were at work, mainly for the safety of space station astronauts"

were not at work as *New Scientist* went to press.

The Republican-led House of Representatives refused to pass the latest funding bill unless Barack Obama agreed to delay his Affordable Care Act, which aims to extend state-funded healthcare. As a result, the government effectively ran out of money.

Fewer than 600 NASA staff were at work, many at mission control in Houston, Texas, ensuring the safety of astronauts on the International Space Station.

Other agencies are similarly hit. The Environmental Protection Agency has a skeleton crew in case of disaster. The National Institute of Standards and Technology has 8 per cent of its workers for tasks such as maintaining atomic clocks, which set the pace of nationwide infrastructure. The National Institutes of Health won't admit new patients for clinical trials and the Centers for Disease Control and Prevention is pausing its annual flu monitoring programme.

The last shutdown began in late 1995, and lasted 21 days.

Oh God, Texas

IF CREATIONISTS in Texas get their way, highschool students throughout the US could soon be reading biology textbooks that falsely cast doubt on the scientific validity of evolution.

The outcome rests with the Texas State Board of Education, whose 15 members will decide in November whether to accept newly drafted biology textbooks, which may contain creationist arguments. Around a third of the board question the teaching of evolution and have sought to introduce amendments undermining its scientific case.

Texas is the second largest state purchaser of school books behind California, so versions sold in the state would likely be sold in many other states too. "Texas could contaminate the education products sold in the rest of the country," says Dan Quinn of the Texas Freedom Network.

60 SECONDS

Did BP do enough?

The second phase of the Deepwater Horizon court hearing began this week, with energy giant BP battling a potential $17.6 billion fine for gross negligence. The New Orleans court will determine how much oil leaked into the Gulf of Mexico in 2010, and whether BP made every effort to stop it or – as the US government argues – it did not try hard enough.

Dark matters more

Forget the Higgs boson: dark matter is where it's at. Only 53 per cent of physicists surveyed at a workshop in Madrid, Spain, believe the Higgs will reveal new insights into fundamental forces, whereas 75 per cent expect that dark matter will be detected within the next decade.

Guns in their sights

The US government has relaunched research into the causes of firearm violence, funding for which was cut in 1996 after pressure from the gun lobby. In January, President Barack Obama ordered work to resume following the massacre at Sandy Hook elementary school in Connecticut last December. Last week, the government began soliciting new research proposals.

War on drugs: #fail

Illegal drugs are now cheaper and purer than at any time in the past 20 years. The International Centre for Science in Drug Policy has analysed data from seven international drug surveillance systems and says that the street price of drugs such as heroin and cocaine has fallen since 1990, even as their potency has increased (*BMJ Open*, doi.org/n3j).

Volcano puzzle solved

A volcanic eruption in 1257 was one of the biggest in the past 7000 years, but its location had been a mystery. Now traces of the blast in ice cores, together with newly analysed rocks, have pinpointed Mount Samalas in Indonesia as the culprit (*PNAS*, doi.org/n3k).

PICTURES OF EARTH 2100

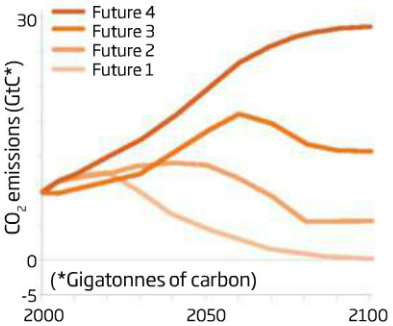
The future is in our hands. Catherine Brahic explores four ways the world might develop in the next century

YOU may have heard last week that Earth in 2100 is likely to be between 0.3 and 4.8 °C warmer than it was in the late 20th century. This is one of the key messages of the latest UN Intergovernmental Panel on Climate Change report. Why such a broad range? Because the rise in temperature depends largely on what we choose to do now – where our energy and food come from, the type of buildings we live in and the cars we drive. And of course, how many people populate the planet.

Those choices will determine whether Earth stays much the same as it is today, or if rising seas eat up major land masses – Florida, Bangladesh, we're looking at you – and large parts of the world become too dry to live in.

Climate scientists combine the various options into descriptions of how human society might evolve, and plug them into their models to see what each scenario would mean for the climate. For ease of comparison, they have agreed on two extreme scenarios and a couple in between. That is what determines the 0.3 to 4.8°C range.

Here, *New Scientist* explores four hypothetical futures for human society in 2100, using criteria set out by climate modellers – though we cannot reproduce the huge amount of data in their scenarios. We have selected some key points and sketched out an image of society in each scenario. To do this, we drew on descriptions published by the IPCC in 2000 and, in consultation with climate modellers, chose the ones that correspond to the concentrations of greenhouse gases published in last week's IPCC report (see page 6).



Changes in carbon emissions over the next century under the four scenarios

It is important to stress that these are just four of the many possible scenarios and ways to cut emissions. But we feel the value of the exercise is in showing how much of the outcome is still in our hands and down to the choices and trade-offs we make as individuals and as society as a whole. For example, a low population opens some options. A high one closes others down, but you could compensate for that by transforming the transport sector, for instance.

"We want people to think about what world they want to live in, and then think about ways that they can make that consistent with a climate future that they want," says Richard Moss of the Pacific Northwest National Laboratory in Richland, Washington, who has been closely involved in developing the climate scenarios.

SOURCES: PCC/AR5 WG1 SUMMARY (2014); CLIMATIC CHANGE, DOI.ORG/BRTF7R (2011); IPCC SPECIAL REPORT: EMISSIONS SCENARIOS (2000); IPCC/AR4 WG2 (2007); INTERVIEWS

SUPERSTOCK

1: GEOENGINEERED SAFETY

Population 9 billion
Global energy use 8×10^{20} joules
CO_2 concentration 400 ppm, dropping

We acted early in the 21st century, invested aggressively in renewable energies and crucially, geoengineering

It wasn't easy, but by investing heavily in R&D, we have built systems for sucking carbon dioxide out of the atmosphere and storing it underground. At the same time, we have invested in renewable energies and virtually weaned ourselves off fossil fuels. The net result: annual carbon emissions have plummeted, and atmospheric concentrations of CO_2 are finally dropping.

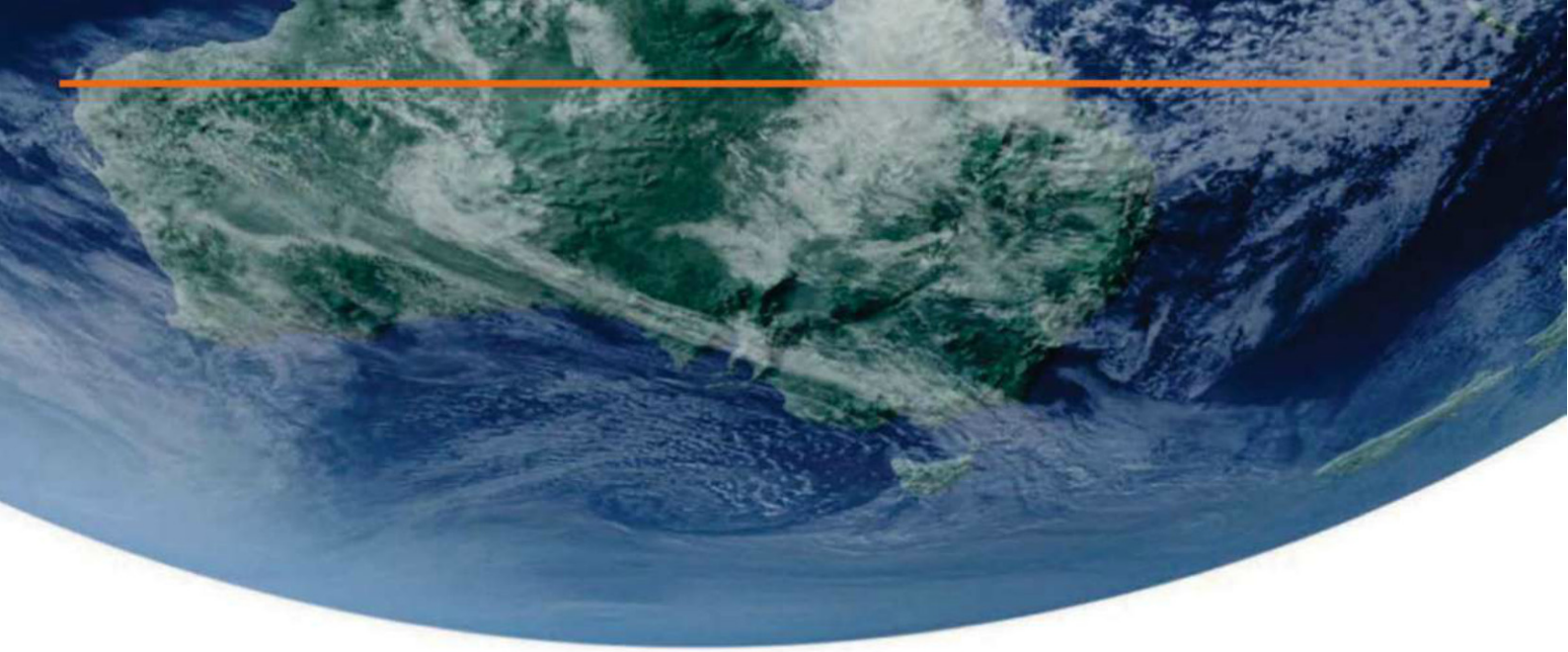
Crucial to making this happen was the spread of bioenergy power plants coupled to carbon storage facilities – a soft form of geoengineering. We grew trees and plants to burn and produce electricity. They suck CO_2 out of the atmosphere as they grow. We captured the greenhouse gases produced when we burn trees, and put the gases in geological seams deep underground – where they will stay for centuries or more.

Global temperatures have held steady since 2050. We've also halted the decline of sea ice in the Arctic and slowed ocean acidification. Sea levels are still rising, though, because of heat stored in the system from earlier emissions.

Temperature rise 0.3-1.7 °C

Water stress intensifies
Increasing risk of species extinctions
Debilitating health effects

Sea level rise 0.26-0.55 m



2: SLIGHT DELAY

Population 8.5 billion
Global energy use 1×10^{21} joules
CO_2 concentration stable at 550 ppm

We delayed both the transition to renewable energies, and the implementation of climate treaties

As a whole, we are a more efficient society than in 2013, using less energy and fewer materials to produce more. We are also good recyclers. All of this makes for better management of natural resources. Earlier on in the century, gas was the transition fuel of choice. Now most of our energy comes from renewables and nuclear. Incentives and better international institutions mean green technologies spread rapidly. We have made the transition to a low-carbon economy.

We eat far less meat than in 2013, to cut the emissions generated by livestock farming. So pastures have shrunk and agriculture is more efficient. Forests are growing, boosting the amount of CO_2 stored in trees around the world.

We live in compact cities with excellent public transport which also limits emissions. Although temperatures and sea levels have risen, some of the more extreme consequences of climate change haven't come to pass.

1.1-2.6 °C

0.32-0.63 m

3: TOO LITTLE, TOO LATE

Population 9.5 billion
Global energy use 8×10^{20} joules
CO_2 concentration 650 ppm and rising

We cut emissions, but not until late in the century

The first half of the century was spent mostly carrying on business as usual: we relied heavily on fossil fuels. We did not introduce any dramatic changes to our life styles or activities in terms of consumption, travel and the number of children we have. Then, towards the middle of the century, the consequences of climate change became too difficult to ignore. As a result, our governments slowly began introducing some unambitious policies to regulate emissions.

We are now slowly making our way towards a green energy supply. Oil consumption started to drop a few decades ago, but 75 per cent of our energy still comes from fossil fuels, not much less than the 82 per cent in 2011.

Because of our inaction, temperatures are still rising, as are sea levels. Models suggest they will continue doing so for several decades more.

1.4-3.1 °C

0.33-0.63 m

"We want people to think about what sort of world they want to live in"

4: ADDICTED TO CARBON

Population 12.5 billion
Global energy use 1.75×10^{21} joules
CO_2 concentration 950 ppm and rising

The world economy is booming, but it's fuelled by coal and oil. The global population continued to grow rapidly throughout the century, pushing emissions ever higher

Welcome to the globalised, high-tech, consumerist future: one where we are still hooked on fossil fuels. Emissions have gone through the roof, and human health and the environment are the casualties. Biodiversity crashes are threatening the normal operation of "ecosystem services" – natural processes such as water recycling through rain and rivers, and pollination.

Most of our energy still comes from fossil fuels, including from unconventional sources, like methane clathrates, tar sands, and fracked shale-gas deposits. Coal is still on the menu. We haven't invested significantly in alternative energies. Globally, we also eat more meat and dairy products than we did in 2013.

Consequently, emissions and temperatures are still rising fast. Droughts and floods are more frequent and claiming more and more lives. Ocean acidification is severe, and getting worse. The Arctic has not had ice during the summer for several decades.

2.6-4.8 °C

0.45-0.82 m

Light kidnapped by black hole lookalike

Jacob Aron

HOW do you see an object when its gravity is so strong that not even light can escape it?

Black holes are inherently mysterious for precisely this reason. Now an artificial black hole has been made that traps light like the real deal – and can be watched in action, safely. As well as demystifying one of nature's weirdest objects, this lookalike may find uses in devices that trap light, like solar cells.

Black holes are most famous for swallowing light, or anything else in their path, a fate that awaits something unlucky enough to pass a point called the event horizon. Less well known is a black hole's photon sphere, a region of warped space-time outside the event horizon that merely traps light in curved paths. No photon sphere has ever been seen because, by definition, trapped light can't reach your eyes.

So to visualise one, Hui Liu at Nanjing University in China and colleagues built an artificial black hole. Real black holes trap light via their immense gravity, something that would be difficult, not to mention incredibly dangerous, to recreate in the lab. Instead, Liu's team used a sheet of plastic, and mimicked gravity by varying the plastic's refractive index, the property that determines how much a substance bends light.

They reasoned that a material with a varying refractive index could bend light like a black hole's photon sphere, but without dangerous levels of gravity.

They created the material by pouring molten acrylic glass onto a spinning quartz sheet and planted a microscopic polystyrene sphere at the centre. The sphere acts as an anchor, causing the glass to solidify thickly at the centre then gradually become thinner further away. "This makes the refractive index vary in the same way the curvature of space varies around black holes," says Liu.

Shining a laser through the glass allows you to watch the artificial black hole in action.

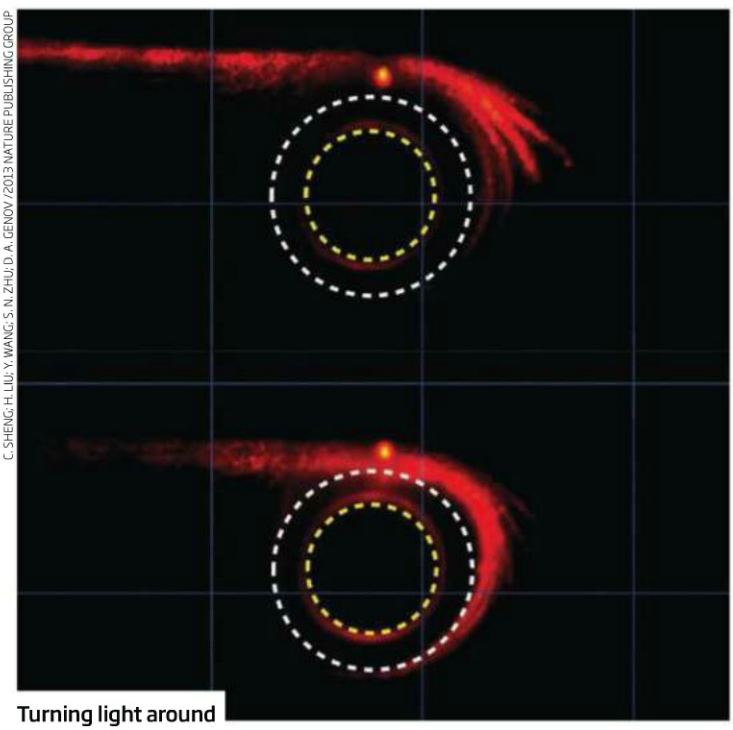
Beams that are relatively far away from the microsphere at the centre of the glass are slightly bent towards it before continuing on their way – mimicking an effect known as gravitational lensing. This can be used to detect galaxies, stars and planets when it occurs in space.

"The material bends light in the same way as the warped space-time around a black hole"

In the case of the artificial black hole, though, the pull increases as the laser moves closer in. Eventually there is a point where the light curves completely around – the first artificial photon sphere (*Nature Photonics*, doi.org/n25). Crucially, unlike in a real black hole, the photon sphere can be seen because Liu's team sprinkled tiny light emitters called quantum dots into the glass. These absorb trapped light and re-emit it at a different angle, allowing it to escape and provide a visible trace (see images, left).

Ulf Leonhardt of the Weizmann Institute of Science in Rehovot, Israel, says it is remarkable to see the mathematics of real black holes – Einstein's equations of general relativity (see "A hairy problem", right) – playing out in a model. "It illustrates that there is no big mystery," he says. "You can do the same with ordinary materials." His team has built mimics of a black hole's event horizon, but not its photon sphere.

Liu adds that the device could be used to study a black hole's tug in more complicated scenarios, while its ability to trap light could be useful in solar cells, photon detectors or microlasers. ■



C. SHENG, H. LIU, Y. WANG, S. N. ZHU, D. A. GENOV /2013 NATURE PUBLISHING GROUP

Turning light around

A HAIRY PROBLEM

With an immense pull and the ability to gobble stuff up, no one can deny that black holes are captivating (see story, left). But they are also hugely important as places where new physics might be on display, such as an extension to Einstein's theory of general relativity. Most recently, this potential was explored via a bizarre-sounding question: do black holes have hair?

The hair in question isn't physical, but a metaphor for individuality. To understand where it comes from, first think about the generic black holes predicted by Einstein's relativity. These can be described completely by their mass, charge and spin. Defined by only those three values, black holes all look basically the same from the outside, even if different objects formed them, or they swallowed different stuff.

This lack of individuality has led them to be called "bald". But many physicists hope that black holes are not bald, and have other properties that arise from parameters other than those three. These would be known as hair – and offer clues as to why Einstein's equations aren't the whole story, something that needs to be solved more generally if relativity is ever to be reconciled with quantum mechanics.

Now Vitor Cardoso of the Technical University of Lisbon in Portugal and colleagues have a new way to give black holes hair. When they added to black-hole models some existing but still unproven extensions to general relativity, they found that in-falling matter can induce extra charge on a black hole. As the charge doesn't arise from any predictions of general relativity, it counts as hair (*Physical Review Letters*, doi.org/n3c). "The black hole grows a wig," says Cardoso.

It's still a theoretical scenario, but if the extra charge can be detected, then an already weird object will be well on the way to solving one of the biggest problems in modern physics – via its hair. Victoria Jaggard

4000-year-old brain opens window on ancient health

No burnt log

HALIC UNIVERSITY ISTANBUL

SHAKEN, scorched and boiled in its own juices, this 4000-year-old human brain has been through a lot.

It may look like nothing more than a bit of burnt log, but it is one of the oldest brains ever found. Its discovery, and the story now being pieced together of its owner's last hours, offers the tantalising prospect that archaeological remains could harbour more ancient brain specimens than thought. If that's the case, it potentially opens the way to studying the health of the brain in prehistoric times.

Brain tissue is rich in enzymes that cause cells to break down rapidly after death, but this process can be halted if conditions are right. For instance, brain tissue has been found in the perfectly preserved body of an Inca child sacrificed 500 years ago. In this case, death occurred at the top of an Andean mountain where the body swiftly froze, preserving the brain.

However, Seyitömer Höyük – the Bronze Age settlement in western Turkey where this brain was found – is not in the mountains. So how did brain tissue survive in four skeletons dug up there between 2006 and 2011?

Meriç Altinoz at Haliç University in Istanbul, Turkey, who together with colleagues has been analysing the find, says the clues are in the ground. The skeletons were found burnt in a layer of sediment that also contained charred wooden objects. Given that the region is tectonically active, Altinoz speculates that an earthquake flattened the settlement and buried the people before fire spread through the rubble.

The flames would have consumed any oxygen in the rubble and boiled the brains in their own fluids. The resulting lack of moisture and oxygen in the environment helped prevent tissue breakdown.

The final factor in the brains' preservation was the chemistry of the soil, which is rich in potassium, magnesium and aluminium. These elements reacted with the fatty acids from the human tissue to form a soapy substance called adipocere. Also known as corpse wax, it effectively preserved the shape of the soft brain tissue (*HOMO – Journal of Comparative Human Biology*, doi.org/nz6).

"The level of preservation in combination with the age is remarkable," says Frank Rühli at the University of Zurich, Switzerland, who has examined medieval brain tissue. Rühli says that most archaeologists don't bother looking for the remains of brain tissue because they assume it is seldom preserved. "If you publish cases like this, people will be more and more aware that they could find original brain tissue too."

"If we want to learn about the history of neurological disorders, we need to have brain tissue like this"

In cases where the brain is as well preserved as this, Rühli says it might even be possible to look for pathological conditions such as tumours and haemorrhaging, and maybe even signs of degenerative disease. "If we want to learn more about the history of neurological disorders, we need to have tissue like this." **Colin Barras** ■

How to grow the hardest teeth in the sea

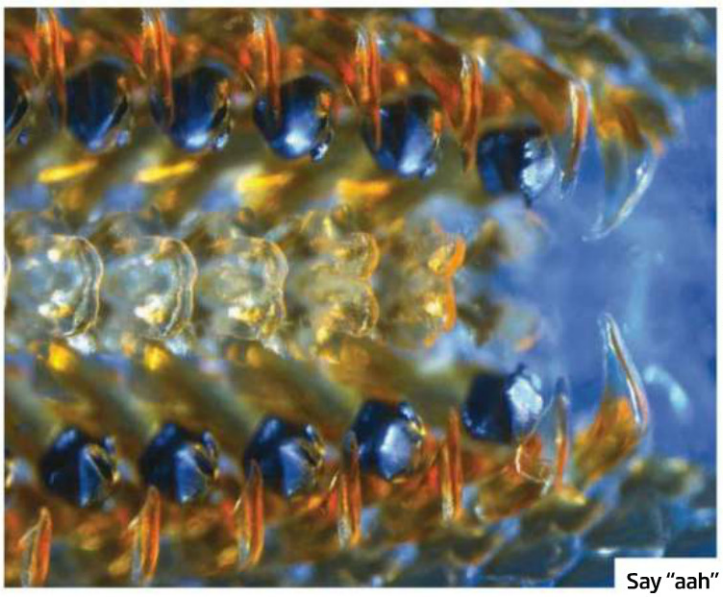
DESPITE their diet of algae, chiton molluscs have the hardest teeth known – and a new atom-probe study is helping us figure out how they grow.

The chiton's black, metallic teeth are made of magnetite, an iron oxide used in electronics and medical devices. Making magnetite often requires high temperature, pressure or acidity – but the chiton does it in its mouth. The question was, how?

Over five years, Lyle Gordon at Northwestern University in Evanston, Illinois, and colleagues have used an atom probe to study the teeth of a fingernail-sized chiton mollusc. The probe plucks charged atoms from a material one at a time, ultimately giving a detailed view inside it.

They found that, in the watery gel at a tooth's centre, proteins and sugars criss-cross to form a scaffold that binds positively charged ions such as magnesium and sodium. Those ions, Gordon suspects, then bind negatively charged proteins that collect iron, providing a complex template for the growing tooth's shell.

Better knowledge of chiton biology could spur manufacturing, says David Bell of Harvard University, who was not involved in the work. "It could be a revolutionary way to produce things." Alyssa Botelho ■



Say "aah"

LYLE GORDON, ENGINEER AT NORTHWESTERN UNIVERSITY

First baby from diced egg therapy

Linda Geddes

A PIONEER is born. But is it too soon? An infertile woman has given birth to a boy following fertility treatment that awakens dormant eggs in women who have stopped menstruating.

The treatment could help women who have left child-bearing too late, or have been left infertile after treatment for cancer. But there are concerns that the technique has been rushed to the clinic before being properly tested.

Women are born with millions of immature eggs, or follicles, but only around 400 mature to the point where an egg is released into the fallopian tubes and can be fertilised. But some of these follicles remain even after a woman has stopped menstruating.

Now researchers have found a way to wake these dormant follicles and produce eggs that are capable of being fertilised. The first test of this technique has resulted in a baby boy, born in December 2012 in Japan.

Immature follicles are usually kept in a dormant state by the *PTEN* gene, which suppresses a signalling pathway involved in cell growth. Aaron Hsueh at Stanford University Medical School in California and his colleagues had previously showed that immature mouse follicles could be stimulated to mature if pieces of ovary were incubated with a molecule that stimulates the pathway inhibited by *PTEN*.

Hsueh's team also discovered that the physical act of cutting up the ovaries disrupts a second signalling pathway, called the Hippo pathway, which normally suppresses the growth of many of the body's other organs as well.

When the cut-up and incubated tissue was implanted back into the mice, eggs were released and fertilised, resulting in the birth of live pups.

Now the team has used a similar process to give women with premature menopause a shot at being mothers, using their own eggs.

Twenty-seven women who had been diagnosed with premature menopause volunteered to have their ovaries removed. Of these, only 13 had any residual follicles left. These women had their ovaries diced up and incubated with a *PTEN* inhibitor, before pieces were transplanted into their fallopian tubes. Ultrasound scans revealed how the follicles were developing.

In all, eight of the women produced mature follicles, and were given drugs to trigger the release of an egg. Five of them produced mature eggs which were harvested and fertilised by IVF. So far, three have had their embryos implanted, resulting in one birth and one ongoing pregnancy. The third failed to implant (*PNAS*, doi.org/n3h).

Ultimately, Hsueh says, the technique could be used to help women who may not be responding to conventional fertility treatment. "This data shows that there are small follicles still sitting there after women have stopped menstruating. This is a way that you can get them to work."

However, Evelyn Telfer, a fertility researcher at the University of Edinburgh, UK, says much more research is needed to ensure the technique is safe before it is routinely used in the clinic. "It's an interesting first step, but we need to do many controlled studies to show that at each stage of the procedure these eggs are normal," she says. "People say it's a baby at all costs, but if the baby is compromised in any way then that's a problem." ■

IMAGE COURTESY OF KAZUHIRO KAWAMURA.

The first of many?

Larks and night owls spotted in the brain

THEY say the early bird catches the worm, but night owls may be missing far more than just a tasty snack. Researchers have discovered the first physical evidence of brain differences that distinguish early risers from people who like to stay up late. The differences might explain why night owls are at greater risk of depression.

Around 10 per cent of people qualify as morning people or larks, and a further 20 per cent are night owls – with the rest of us falling somewhere in between.

Previous studies have suggested that night owls experience worse sleep, more daytime tiredness and consume more tobacco and alcohol. This has prompted some to suggest they have a form of chronic jet lag.

To investigate, Jessica Rosenberg at RWTH Aachen University in Germany and colleagues scanned the brains of 16 larks, 23 night owls and 20 who lay in between. They found a reduction in the integrity of night owls' white matter – brain tissue comprised of fatty insulating material that speeds up nerve signals – in areas associated with depression (*NeuroImage*, doi.org/n28).

"We think this could be caused by the fact that [night owls] suffer from this permanent jet lag," says Rosenberg, although studies are needed to confirm cause and effect.

"It's interesting that there are differences," says Derk-Jan Dijk, director of the Surrey Sleep Research Centre in Guildford, UK, "but we need to understand what is causing them and find ways of creating environments in which those differences can be attenuated."

"People's work schedules should change to fit in with their natural sleep patterns"

Rosenberg suggests that people's work schedules should change to fit in with their natural sleep patterns, but Djik says there may be an easier way. Research suggests that night owls who boost their exposure to sunlight find their body clocks shift towards earlier waking and sleeping. Linda Geddes ■

Hunting quantum gravity in the big bang's echoes

UNITING gravity with its quantum nemesis might take a detector the size of the universe. So say two physicists who think they have found a way to resolve one of the biggest conflicts in modern physics using high-resolution maps of the infant cosmos.

The universe is currently described using two distinct frameworks: gravity for larger objects such as planets and black holes, and quantum mechanics for the tiny world of bosons and quarks. Even though almost everyone expects these realms to be linked, no one has been able to build a bridge between the two. Previous work focused on trying to finding the graviton – the quantum unit of gravity – the sheer existence of which would unite the two theories.

"It's actually very hard to construct a consistent theory in which gravity is not quantised but the rest of the world is," says Steven Carlip at the University of California, Davis.

Three of the four fundamental forces are proven to be carried by their own particle, such as the photon that carries electromagnetism and the gluon that carries the strong force. So it makes sense that gravity should also have its own particle – the graviton. But gravity is the weakest force of the four, so it would take something very massive to have the sensitivity required to detect a lone graviton. Some researchers have even suggested that it will be impossible to ever find them, because a sufficiently sensitive detector would have to be so massive it would collapse into a black hole.

Now, Nobel laureate Franck Wilczek of the Massachusetts Institute of Technology and Lawrence Krauss of Arizona State University in Tempe suggest that our best shot may be to find ancient ripples in space-time called gravitational waves, which are predicted by general relativity.

Instead of hunting the graviton directly, they say, look to maps of the cosmic microwave background (CMB), the first light that travelled across the universe after the big bang (see photo). Such maps give strong evidence that the cosmos rapidly expanded during its first fractions of a second. That burst, called inflation, should have triggered gravitational waves that would have scattered the photons of the CMB in preferred directions, creating patterns of orientation in the light that are an imprint of the relic waves.

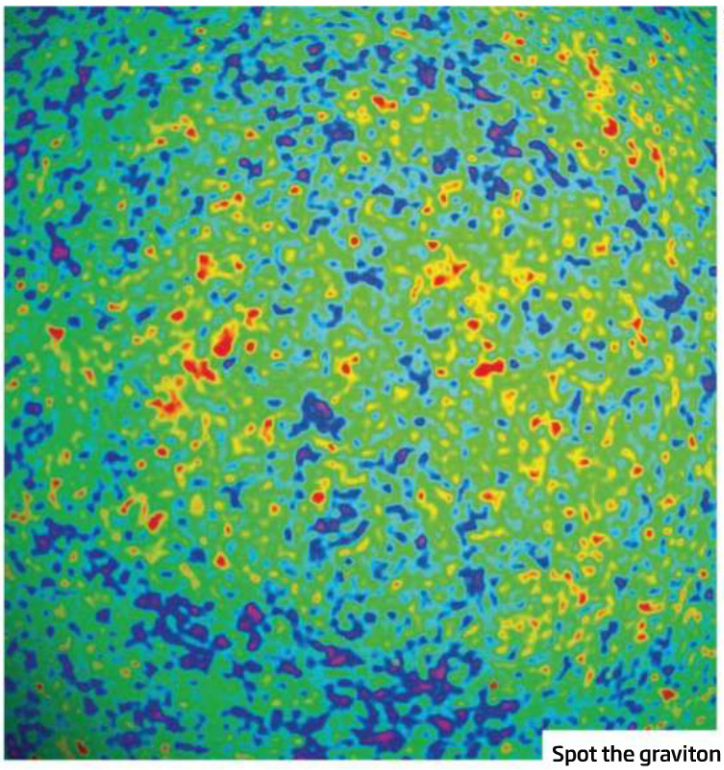
Wilczek and Krauss say that if we can find those imprints, we would have our long-sought evidence for quantum gravity. That's because using a tool called dimensional analysis, they found a positive link between the primordial gravitational waves and Planck's constant, which is used in quantum mechanics. That means quantum-mechanical activity would have been needed to create the gravitational waves during inflation, Wilczek says (arxiv.org/1309.5343).

The idea is plausible, although it relies on a few unstated assumptions, says Carlip. For instance, physicists will need to be able to show that the polarisation of the CMB is down to the proposed primordial gravitational waves and not the result of some other process.

"If we can find those imprints, their existence would be evidence for quantum gravity"

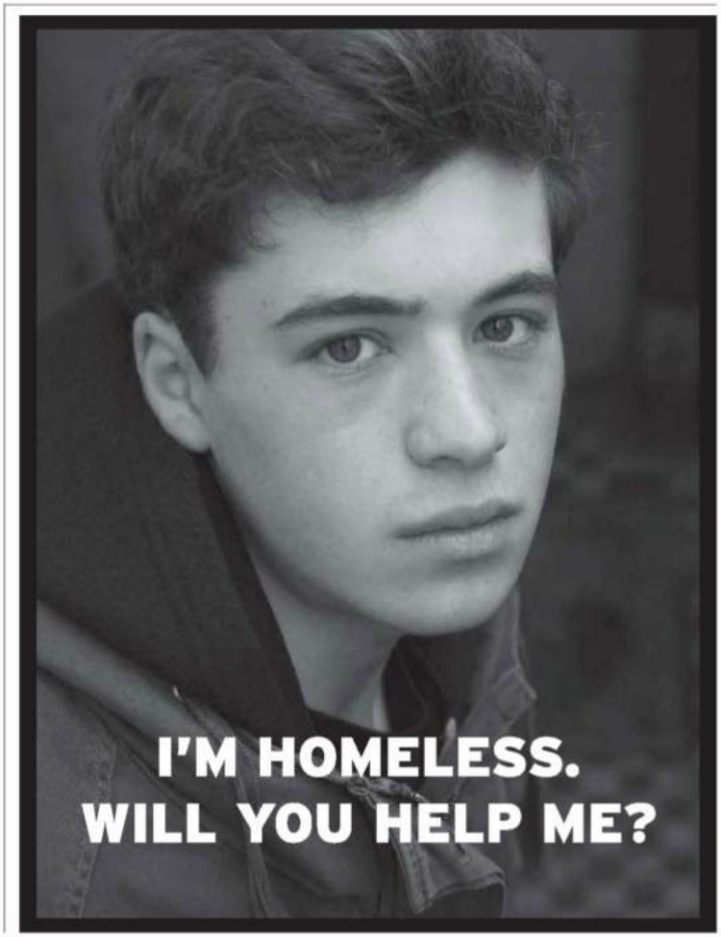
Wilczek reckons we will not have the sensitivity to detect the influence of primordial gravitational waves in the CMB for at least 10 to 15 years, despite new high-resolution maps from the Planck satellite.

However, if the waves really are quantum in nature, it will be worth the wait. "Most theoretical groups are convinced the gravitational field should be quantised," says Wilczek. "But while no one was surprised by the existence of the Higgs particle – based on theoretical predictions – it's quite another thing to see the damn particle." Victoria Jaggard ■



WMAP

Spot the graviton



Preserved nerves control robot leg

Colin Barras

A MAN missing his lower leg has gained precise control over his prosthetic limb, just by thinking about moving it – all because his unused nerves were preserved during the amputation and diverted to his thigh where they communicate with a robotic leg.

He can now seamlessly switch from walking on level ground to climbing stairs and can even kick a football around (see him in action at bit.ly/roboticleg).

During traditional amputation, sensory nerves are severed and lose their function. In 2006, Todd Kuiken and his colleagues at the Rehabilitation Institute of Chicago realised they could preserve some of that functionality by rerouting sensory nerves and attaching them to another part of the body.

The nerve signals were then available for a robotic limb, enabling a person to control their prosthesis with the same nerves they had originally used to control their real limb.

Kuiken's team first attempted the procedure – called targeted muscle reinnervation (TMR) – on people who had to have their arm removed. Now he has performed TMR for the first time on a leg amputation.

During the surgery, the team rerouted the two main branches of the patient's sciatic nerve to muscles in the thigh. One branch controls the calf and some foot muscles, the other handles outside leg muscles and some more foot muscles.

After a few months, the man could control his thigh muscles by thinking about using his missing leg. The next step was to link up a prosthesis.

The robot leg in question is already very sophisticated: it carries a number of mechanical sensors including gyroscopes and accelerometers, and uses information from these sensors for certain walking styles. Kuiken's team reckoned that the leg would be even more useful if it could infer the user's intended walking style with information from the sciatic nerve.

So first, they asked their volunteer to try to make movements with his missing leg – flexing the foot, for instance – while they monitored the pattern of electric signals from the redirected nerves in the thigh muscles. Then they programmed the prosthesis to flex its foot whenever it detected that pattern.

REHABILITATION INSTITUTE OF CHICAGO

I think therefore I walk

Using just mechanical sensor data, the robotic leg made the correct movement about 87 per cent of the time. With additional nerve data, the success rate rose to 98 per cent, and there were no critical errors, which increase the risk of the user losing balance (*NEJM*, doi.org/n2h).

"There's a lot you can do with physical sensors but at some point you really need to know the user's intent," says Michael Goldfarb at Vanderbilt University in Nashville, Tennessee, who helped design the robot leg. "This new generation of prostheses can pretty much do whatever the healthy limb can do." ■

Lack of folic acid in pregnancy hits generations

WHETHER or not a mother has enough folic acid during pregnancy could affect not only the health of the child, but also that of future generations.

That's the suggestion from a study in mice showing that folic acid deficiency triggers abnormalities in their pups and grandpups.

It is well known that a lack of folic acid – a vitamin necessary for protein formation – during pregnancy can result in birth defects or low birth weight, but how it does so is unclear. To investigate, Erica Watson at the University of Cambridge bred mice with a mutation in the *MTRR* gene, involved in folic acid metabolism. The mutation's effect is similar to withdrawing dietary folic acid but is easier to control experimentally.

When the mutated mice were mated with normal mice, some of the fetuses developed abnormalities such as heart defects and spina bifida. Only their siblings without defects survived to term and when these were mated with normal mice, the next generation had the same problems, as did two subsequent generations (*Cell*, doi.org/n24).

The effects occurred even though the pups and grandpups were free of the *MTRR* mutation, which suggests they were inherited not through DNA itself but through changes in the gene-switching system, says Watson.

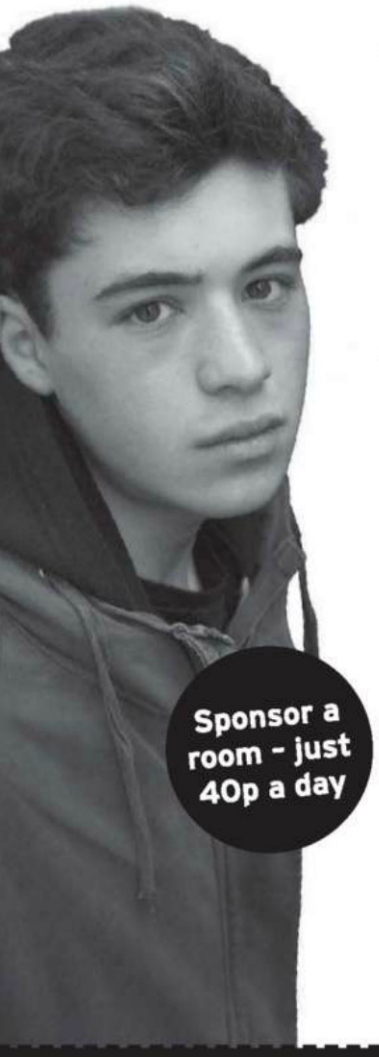
This "epigenetic" system turns genes on and off through the addition of chemical tags, such as methyl groups. Until recently, it was assumed that these epigenetic marks were wiped clean after each generation. But when Watson's team examined the DNA of offspring of mice deficient in folic acid and those of the next generation, they found widespread changes in methylation.

"The mouse pups had abnormalities because one of their grandparents had been folic acid deficient"

The work supports the growing evidence that trans-generational epigenetic changes exist and are important for human health, says Tim Spector of King's College London. Linda Geddes ■

DID YOU SEE MARK?

Have a look at page 13. Did you see him? Or did you look past him and carry on with your life?



Sponsor a room - just 40p a day

Like many homeless young people that come to Centrepoint. Mark is used to being ignored. Caught in the crossfire of abusive parents as a child, the only attention he ever got was when they turned their anger on him. Bullied mercilessly at school, he soon fell out of education.

"I was 14, I didn't know how to cope with the isolation. I followed my parents' example. I turned to alcohol as a prop."

For a while Mark beat the odds. He got a job as a trainee chef and his prospects looked brighter. But things at home got tougher, and his alcohol dependence worsened. When his parents finally separated, they said he was surplus to requirements. With nowhere else to go, he spent his first night on the streets.

"It was one night, then another. Six months later I was still there. I was alone and depressed, I didn't know how to get free."

With no money and no one to support him, Mark hit rock bottom. He went to a park, found a tree, and tried to hang himself with his belt. The belt snapped, but worse was yet to come. He was mugged, badly beaten and left for dead.

Mark's story is appalling. But it is not unique. Many of the homeless young people who come to Centrepoint have been through similar experiences. Victims of neglect, abuse or family breakdown, they are fleeing chaotic backgrounds that rob them of their dignity. When they find themselves forced onto the streets, they are easy targets for drug dealers, pimps and assailants - often within a matter of hours.

By sponsoring a room at Centrepoint - for just 40p day (£12 a month) - you could give a vulnerable homeless young person like Mark a safe, warm room of his own right now.

The Centrepoint room sponsorship scheme offers homeless young people like Mark a real chance to get their lives back on track, starting with a roof over their heads and ongoing support.

Homeless young people are struggling to be seen and heard on the streets even now. They urgently need our help to pick up the pieces and to rebuild their broken lives. Please be the person to give them that help - and the chance of a fresh start and lasting change - today. Please, give 40p a day now.

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Visit www.centrepointroom.org.uk/newscientist8
or return the form below

Why become a Centrepoint Room Sponsor?

- For just 40p a day, you could help a young person escape homelessness forever
- You'll receive a welcome pack and regular updates about the progress of young people you're supporting
- 80% of young people who come through Centrepoint go on to find education, employment or their own home
- 86p of every pound we spend goes directly towards services for homeless young people

centre point give homeless young people a future

Your regular gift will be used to assist young people in sponsored rooms and for the general purposes of Centrepoint - working with homeless and socially excluded young people.

Will you sponsor a Centrepoint room and get a homeless young person off the streets for good?

☐ **I wish to sponsor a room at £12 a month**
☐ **I wish to sponsor two rooms at £24 a month**
☐ **I wish to sponsor ___ rooms at £ _____ a month**

Please collect my payment on the 1st/15th of every month (please circle preferred date)

Instruction to your Bank or Building Society to pay by Direct Debit DIRECT Debit

To The Manager: Originators Identification No. 6 5 9 1 0 7
Name and full address of your Bank or Building Society:

Postcode

Name(s) of Account Holder(s)

Bank Sort Code: ☐☐-☐☐-☐☐ Account Number: ☐☐☐☐☐☐☐☐

Instructions to your Bank or Building Society: Please pay Centrepoint Direct Debits from the account detailed in this instruction, subject to the safeguards assured by the Direct Debit Guarantee. I understand that this instruction may remain with Centrepoint and, if so, details will be passed electronically to my Bank/Building Society.

Signature(s) Date

Banks and Building Societies may not accept Direct Debit Instructions for some types of account

To protect the privacy of those we help, a model has been used for the photograph and the name has been changed. The story however is true and as told by a young person.

RAP1314A-06L

Full Name

Address

Postcode

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☐ I'd like to receive important news and updates about my support. I have included my email address below.

Email

In accordance with the 1998 Data Protection Act, we hold your details to provide you with updates and appeals. If you do not wish to receive these please contact Centrepoint.

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centre point

MAURICE SMITH/PHOTONONSTOP/CORBIS

Small islands are catastrophe for small mammals

NO ANIMAL is an island. Mammals marooned on small islands or in isolated forest fragments are more vulnerable than anyone knew. A case study in Thailand suggests they can go extinct in just 25 years. This is worrying because ecosystems around the world are being diced up as human activities encroach.

When Thailand flooded a rainforest to build a dam in 1986, it created an opportunity to study how isolation affects mammal populations. Poking above the waters of the new Chiew Larn reservoir were 100 islands of tropical rainforest. William Laurance from James Cook University in Cairns, Australia, and colleagues identified 16 islands, varying in size from 0.3 to 56.3 hectares, and measured how quickly the small mammals there became extinct.

Five years after the flooding, the nine fragments under 10 hectares had lost almost all of their small mammals. Twenty years later, the larger islands had met the same fate. The only mammal left in any abundance was the Malayan field rat, an invasive species that had colonised the islands. The native species had declined so much – due to competition with the rats and inbreeding – that on many islands, researchers could only find a single individual (*Science*, doi.org/n2r).

"It's a very striking and catastrophic decline of biodiversity," says Laurance, and it emphasises the importance of linking habitats to create larger reserves.

Xenon and iron, a match made in the core

IS EARTH'S core playing cupid? It seems that xenon, a normally inert gas, can pair up with iron under the extreme conditions there. This could explain why our planet appears to lack xenon.

The atmosphere contains just 1/20th of Earth's expected total xenon, as revealed by analyses of meteorites that should have a similar make-up to Earth.

To see if the missing xenon is trapped in the planet's core, Yanming Ma of Jilin University in Changchun, China, and colleagues used a supercomputer to model the element's reactivity. Xenon would not normally react with iron – which makes up 85 per cent of the core – but at pressures of about 300 gigapascals and temperatures of about 6000 °C, found in Earth's core, the two seemed attracted to one another.

A compound can form from one xenon and three iron atoms. Because it has lower energy than the sum of the pure elements' energies under those conditions, it is the preferred state (arxiv.org/abs/1309.2169).

Ma's team found that xenon could even react with nickel, a minor component of the core. "Earth's core is a natural reservoir for xenon," Ma says. So it could be that iron's hot embrace is to blame for Earth's missing xenon.

The Red Planet's supervolcanic past

MARS had a Yellowstone all of its own. And like the one lurking under the US national park, it went bang in a series of vast explosions that could have shaped the planet's entire future.

The biggest known volcanoes on Mars, like Olympus Mons, coughed up lava slowly. But on Earth, supervolcanoes have been known to release 1000 cubic kilometres of lava and ash in a single explosive outburst.

When NASA's Jacob Bleacher and his colleagues studied images of crater-like features in Mars's Arabia Terra, they concluded that their size, depth and structure are good matches for supervolcano calderas. Each behemoth could have spat out between 4600 and 7200 cubic kilometres of lava and ash, they say (*Nature*, DOI: 10.1038/nature12482).

Such eruptions would have had a big impact on Mars's climate and suitability for life, the team says.

Ocean's black holes trap warm water

BLACK holes famously trap everything in their path. Now it seems swirling eddies in the ocean are mathematically the same – and could help to slow climate change.

George Haller at the Swiss Federal Institute of Technology in Zurich and colleagues showed that eddies' boundaries satisfy the same equations as the area surrounding black holes in general relativity. That helped them spot seven new whirlpools in the South Atlantic Ocean, off the coast of Africa (*Journal of Fluid Mechanics*, doi.org/n26). Previous studies suggest such eddies could carry warm water away from southern sea ice. That could help slow the ice's melting, which affects global currents and weather.

Bulgy Earth keeps sky from falling

SATELLITES stay in their orbits thanks to Earth's squashed shape – something we've only just discovered.

Our planet is ringed by more than a thousand working satellites, and for the most part they stay up there quite happily. But it is only now that we understand why.

Ideally, a tiny satellite orbiting a perfectly spherical planet will remain there forever, assuming nothing nearby disturbs it. But Earth is not a perfect sphere, and many things can disturb its low-orbiting satellites – first and foremost, the moon. According to the laws of motion, the moon's influence alone should cause satellites to crash into the atmosphere and burn up.

It turns out that Earth's imperfections are the satellites' saving grace. Because of its rotation, the Earth is slightly squashed at the poles and bulges around the equator.

According to analysis by Scott Tremaine at the Institute for Advanced Study in Princeton, New Jersey, the pull of the bulge shifts satellites' orbits over time. This prevents tugs from the moon and other sources pulling the orbits too far in one direction or another (arxiv.org/abs/1309.5244v1). If the Earth were a more perfect sphere, many satellites would crash and burn in a matter of months or years.

NASA/SPL

Neural stem cells pulled from brain using magnet

IT'S like pulling a rabbit out of a hat. Researchers have reached inside the brain of a rat and pulled out neural stem cells – without harming the animal.

Since the technique uses nanoparticles already approved for use in humans, it is hoped that it could be used to extract neural stem cells from people to treat conditions like Parkinson's, Huntington's and multiple sclerosis.

Extracting neural stem cells (NSCs) from the person who needs them would avoid immune rejection – but they are difficult to remove safely. So Edman Tsang at the University of Oxford and his colleagues have developed a technique to safely fish out NSCs that originate in cavities in the brain called ventricles.

Tsang's team coated magnetic nanoparticles with antibodies that bond tightly to a protein found on the surface of NSCs. They then injected the nanoparticles into the lateral ventricles of rats' brains. Six hours later, after the nanoparticles had bonded to the NSCs, the researchers used a magnetic field around the rats' heads to pull the stem cells together. They could then be sucked out of the brain with a syringe.

After freeing the stem cells from the nanoparticles, the team found they could grow them in a dish, suggesting they were undamaged by the process.

The rats, meanwhile, were back on their feet within hours of the surgery, showing no ill effects (*Angewandte Chemie International*, DOI: 10.1002/anie.201305482).

Modified mice cry stem cell tears

IT'LL make you cry, or salivate. Takashi Tsuji at Tokyo University of Science in Japan, and colleagues have created tear and salivary glands from stem cells and successfully transplanted them into adult mice.

The technique could one day be used in humans to replace glands lost through age or illnesses such as autoimmune disease and cancer.

To create the glands, Tsuji's team extracted two types of stem cells from a mouse embryo and grew them in a mix of chemical growth factors. The cells began mimicking the interactions that occur in embryos, developing into primitive glands, which were transplanted into adult mice that lacked salivary or tear glands.

A month later, the glands had connected with the nervous system and delivery ducts. When the researchers stimulated the digestive tracts of the mice with salt, the bioengineered glands produced saliva. Similarly, cooling their eyes made the engineered glands produce tears, complete with the proteins and lipids usually found in teary secretions (*Nature Communications*, DOI: 10.1038/ncomms3498).

RIA NOVOSTI/TOPFOTO

USSR's fall was great for emissions

THE collapse of the USSR created the largest ever human-made carbon sink.

In 1991, the Soviet Union formally split into separate republics. The loss of government subsidies and privatisation of land led to one of the biggest land-use changes of the 20th century: 455,000 square kilometres of farmland were abandoned.

Ever since, plants have been reclaiming the land and locking in carbon as they grow. The rate of plant growth depends on the type of soil, so Irina Kurganova of the Russian Academy of Sciences in Pushchino mapped soil types across the former USSR and overlaid it with a map of land-use change. Using all available data on the amount of carbon stored in different regions, she calculates that altogether, the abandoned land has locked away 42.6 million tonnes of carbon every year since 1990 (*Global Change Biology*, doi.org/n2k).

This is equivalent to storing 10 per cent of Russia's annual carbon dioxide emissions from fossil fuels.

"Everything like this makes a difference," says Jonathan Sanderman of CSIRO Land and Water in Australia, but he notes that it came at the cost of huge hardship.

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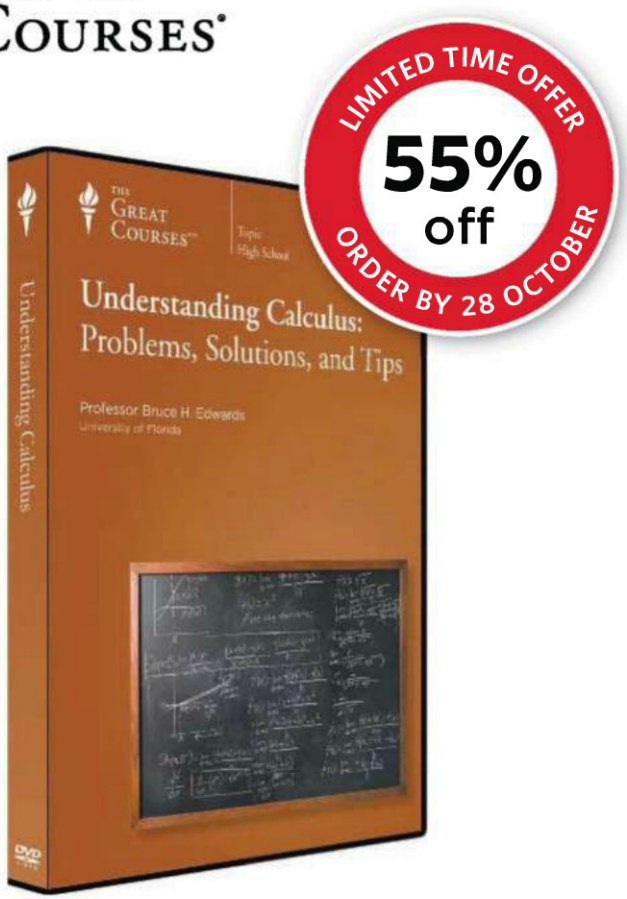

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SENSPROUT

Digital filigree

Tear me to share me

Circuits laid down on paper by inkjet printers will make electronics more creative and versatile – and easier

Paul Marks

"IMAGINE printing out a paper computer and tearing off a corner so someone else can use part of it." So says Steve Hodges of Microsoft Research in Cambridge, UK. The idea sounds fantastical, but it could become an everyday event thanks in part to a technique he helped develop.

Hodges, along with Yoshihiro Kawahara and his team at the University of Tokyo, Japan, have found a way to print the fine, silvery lines of electronic circuit boards onto paper. What's more, they can do it using ordinary inkjet printers, loaded with ink containing silver nanoparticles. Last month Kawahara demonstrated a paper-based moisture sensor at the Ubicomp conference in Zurich, Switzerland.

Kawahara says the idea is perfect for the growing maker movement of inventors and tinkerers. Hobbyists will be able to test circuit designs by simply printing them out and throwing away anything that doesn't work. That will reduce much of electronics to a craft akin to "sewing or origami", he says.

Kawahara and Hodges say the idea also fills a gaping void in the capabilities of 3D printers, which can print the casing for a gadget but not the printed circuits that go inside it. Research on 3D printing conductive elements inside structures has not yet reached a level of sophistication for it to be useful.

"Designing a printed circuit board is not a trivial thing at all. So many people talk about 3D printing an iPhone, when all you can actually do is print a few limited components of one," says Matt Johnson, founder of London firm Bare Conductive, which makes conductive ink for hobbyists. He says there need to be easier ways for people to create circuitry that could lend itself to novel applications such as packaging (see "Ink gets wired for sound").

The ink used by Kawahara's team is a silver suspension recently developed by Mitsubishi Chemical in Tokyo. Kawahara tried it out in an $80 inkjet printer and discovered that it worked well on photo-quality paper. The ink needs no heat to release its silver, and the particle size, viscosity and surface tension were just right for it to deposit flat silver conductors onto the paper. To turn these into working circuits, the team avoided soldering – which would have burned through the paper – and instead used a conducting glue to attach components like resistors and capacitors.

"Hobbyists can test circuits by simply printing them out, reducing electronics to a craft akin to sewing"

The moisture sensor the team has printed is meant for use on plants (see picture). It detects rainfall with one circuit and soil humidity with another, transmitting its readings via a printed Wi-Fi antenna. Hodges has printed paper wiring to connect the switch, LED and battery of a 3D-printed flashlight.

In addition, the team has shown off more complex inkjet-printed circuits, with microprocessors and memory chip connectors. In principle, these could be used to create paper-based computers that would continue to work even when broken into smaller pieces. Jürgen Steimle at the Massachusetts Institute of Technology is already developing "redundant" circuit layouts with this capability, including circuitry for touchpad-like devices that work even if one part has been cut out. It raises the prospect of printed devices that people could simply tear to share.

If silver-based inkjet printing can be made affordable, Hodges says it will be a natural follow-on to Bare Conductive's hand-drawn and paintable circuitry. Kawahara goes further: "In 20 years you really will be able to hit 'Print' and make yourself a mobile phone". ■

Ink gets wired for sound

Bare Conductive is a London-based start-up that makes conductive ink (see main story). This allows touch-sensitive light switches to be painted on worktops, for example. The firm also makes greeting cards that children can draw on using pens filled with the ink, connecting up batteries to LEDs to make them flash.

Now the firm wants to add audio output to its cards – and future interactive packaging – using a circuit it calls a TouchBoard. The size of a playing card, it features a simple to use Arduino processor and an MP3 chip that plays music, stories and sound effects when someone taps the painted-on, conductive buttons. A Kickstarter campaign to build TouchBoard is about to be launched.

Hide your data from prying eyes

Gatekeeper software lets you control who is accessing information about you

Hal Hodson

BIG BROTHER is watching you. But that doesn't mean you can't do something about it – by wresting back control of your data.

Everything we do online generates information about us. The tacit deal is that we swap this data for free access to services like Gmail. But many people are becoming uncomfortable about companies like Facebook and Google hoarding vast amounts of our personal information – particularly in the wake of revelations about the intrusion of the US National Security Agency (NSA) into what we do online. So computer scientists at the Massachusetts Institute of Technology have created software that lets users take control.

OpenPDS was designed in MIT's Media Lab by Sandy Pentland and Yves-Alexandre de Montjoye. They say it disrupts what NSA whistleblower Edward Snowden called the "architecture of oppression", by letting users see and control any third-party requests for their information – whether that's from the NSA or Google.

If you want to install an app on your smartphone, you usually have to agree to give the program access to various functions and to data on the phone, such as your contacts. Instead of letting the apps have direct access to the data, openPDS sits in between them, controlling the flow of information. Hosted either on a smartphone or on an internet-connected hard drive in your house, it siphons off data from your phone or computer as you generate it.

It can store your current and historical location, browsing history, content and information related to sent and received emails, and any other personal data required. When external applications or services need to know things about you to provide a service, they ask openPDS the question, and it tells them the answer – if you allow it to. People hosting openPDS at home would always know when entities like the NSA request their data, because the law requires a warrant to access data stored in a private home.

"We want people to have access to their data. Today, AT&T has access to my GPS data, but I don't"

Pentland says openPDS provides a technical solution to an issue the European Commission raised in 2012, when it declared that people have the right to easier access to and control of their own data. "I realised something needed to be done about data control," he says. "With openPDS, you control your own data and share it with third parties on an opt-in basis."

Storing this information on your smartphone or on a hard drive in your house are not the

3D-printed objects outgrow their printers

3D PRINTING may be set to change the world by letting us make all sorts of bespoke objects, but there's one little problem: the printers can only print items smaller than themselves. Until now, that is.

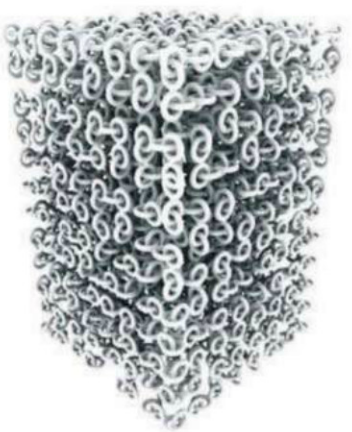
Skylar Tibbits at the Massachusetts Institute of Technology's Self-Assembly Lab and his colleague Marcelo Coelho have come up with a way for standard 3D printers to print out large objects.

The approach, called Hyperform, converts the desired object into a single, long chain made from interlocking links. An algorithm works out how that chain can be packed together into the smallest cube possible using a Hilbert curve – a fractal-based pattern that is the most efficient way of squeezing a single line into a given space. The resulting cube is small enough to be printed by a standard 3D printer.

Once this cube is printed, the chain can be unravelled and assembled by hand to create the desired object. That's possible because each link in the chain has notches that allow it to bend only in a certain way. "You have to fold it by hand and click it into place," says Tibbits.

Last month, Hyperform won the The Next Idea award at the Ars Electronica 2013 technology festival in Linz, Austria.

Hyperform has so far been used to create a chandelier, and Tibbits sees it as the perfect way to produce large 3D-printed consumer products. But it must be used in conjunction with a printer capable of printing at



Printer ready

PLAINPICTURE/AURORA PHOTOS

They know where you are

only options. ID3, an MIT spin-off, is building a cloud version of openPDS. A personal data store hosted on US cloud servers would still be secretly searchable by the NSA, but it would allow users to have more control over their data, and keep an eye on who is using it.

"OpenPDS is a building block for the emerging personal data ecosystem," says Thomas Hardjono, the technical lead of the MIT Consortium for Kerberos and Internet Trust, a collection of the world's largest technology companies who are working together to make data access fairer. "We want people to have equitable access to their data. Today, AT&T and Verizon have access to my GPS data, but I don't."

Other groups also think such personal data stores are a good idea. A project funded by the European Union, called digital.me, focuses on giving people more control over their social networks, and the non-profit Personal Data Ecosystem Consortium advocates for individuals' right to control their own data.

OpenPDS is already being put to use. Massachusetts General Hospital wants to use the software to protect patient privacy for a program called CATCH. It involves continuously monitoring variables including glucose levels, temperature, heart rate and brain activity, as well as smartphone-based analytics that can give insight into mood, activity and social connections. "We want to begin interrogating the medical data of real people in real time in real life, in a way that does not invade privacy," says Dennis Ausiello, head of the hospital's department of medicine.

OpenPDS will help people keep a handle on their own data, but getting back information already in private hands is a different matter. "As soon as you give access to that raw data, there's no way back," says de Montjoye. ■

much higher resolutions than standard consumer 3D printers. The team is using the Form 1 printer, built by start-up firm Formlabs, which is capable of printing layers just 25 micrometres thick.

The resins these printers use have limitations in terms of strength, though, and the chain design weakens things further. "If you want to make large-scale furniture or buildings, there needs to be an approach to make them stronger," says Tibbits.

Manually clicking each link into place isn't ideal either. That's where Tibbits' other work in "4D" printing might help. 4D printing uses materials that are 3D-printed to produce an intermediate object that, when exposed to water, will bend and twist itself into the final structure. "You can see how Hyperform and 4D printing are pointing towards each other," he says.

Clément Moreau, CEO of French 3D printing firm Sculpteo, says projects like Hyperform are shaping the future of 3D printing. "This is yet another example of how 3D printing constantly opens up new possibilities in terms of materials used and shapes which can be printed." Niall Firth ■

SKYAR TIBBITS & MARCELO COELHO/FORMLABS INC.

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MARTIN PARR/MAGNUM PHOTOS

Take a 3D tour with Wikipedia

Wish you were here? Bryan Russell at the University of Washington in Seattle and colleagues have developed the first online system that automatically creates annotated 3D reconstructions of tourist sites. To build up the visualisation, off-the-shelf software grabs images from online photo sites such as Flickr and stitches them together in three dimensions. The system uses Wikipedia entries for the site to annotate the visual model. Users can zoom in on a feature, or, where a narrative sequentially describes a site, they can embark on a fly-through to visualise the description.

"I just used my phone for about 20 minutes and now I feel like I'm going to vomit"

One of many complaints on an Apple forum that animations in the iOS 7 operating system are making users nauseous

Bringing a PC to the console battle

Watch out Xbox One, PlayStation 4 and Wii U – Steam Box is gearing up for a fight. US video game firm Valve fired off a salvo of announcements last week outlining its plans to bring PC gaming to gamers' living rooms. The company said that next year it would release a compact PC, the Steam Box, as well as a Linux-based operating system, SteamOS, and a videogame controller with super-precise touchpads that mimic the feel of a mouse and keyboard.

Careful what you say

Our words are a dead giveaway. The language we use speaks volumes about our personality, says Saif Mohammad at the National Research Council Canada. He has built software that analyses the sentiment of the language in a series of essays, and gauges each author's personality. When evaluating anonymous essays, most of the time it agreed with psychologists' assessments of where the author fell among the "Big Five" personality traits of extroversion, neuroticism, agreeableness, conscientiousness and openness.

INSIGHT Bank heists

MOVIESTORE COLLECTION/REX

The old-fashioned way

How to hack a bank

Forget shotguns and ski masks – today's thieves hack their way in

EARLIER this year, a man walked into a branch of Barclays in north London and stole £1.3 million without touching a single bank note. Instead, he posed as an IT technician and installed a device to siphon off the cash electronically.

News of the robbery emerged last month when eight men were arrested, a week after police foiled a similar plot against Santander. It seems that bank robbers are giving up shotguns for software. Here's how they do it.

Bogus tech support

The Barclays and Santander plots involved installing a device called a keyboard video mouse switch. This is commonly used in data centres to control multiple computers from a single terminal, and by connecting it to a 3G router the crooks were able to remotely access Barclays' machines over the cellphone network. They used this to transfer money to their own accounts, but Barclays noticed and reported the theft a day later.

"The hard part is not getting in the bank to do the transfer, but getting the money out of the bank into some form you can spend without getting caught in the process," says Steven Murdoch, a security researcher at the University of Cambridge.

Convert your way to wealth

One unlikely way to take a bank's cash involves currency conversion. Swap $10 for pounds through your online account and you will receive £6.22 at current rates – your bank rounds to the nearest pence. But if you exchange one cent, the rounding means you will get one pence, a significant profit. Set software to do this over and over, and soon you will be sitting on a tidy sum.

"One bank lost €30,000 before anyone noticed the currency conversion scam and could stop it"

Banks prevent this by setting a minimum conversion amount or limiting the number of exchanges per day, but some have only realised they were under attack once it was too late. "Two of our banking customers have lost money through currency rounding attacks," says Mitja Kolsek of Acros Security in Maribor, Slovenia. "One of them lost around €30,000 before it noticed and blocked it."

Clone cards

Credit and debit cards are often targeted by criminals, either by stealing individual cards or modifying ATMs to record card details and PINs. The account details are copied on to blank cards and then used to withdraw money or buy goods to sell on.

Many countries use a chip and PIN system to prevent this, so criminals have got into the habit of taking cloned cards to the US, where the system isn't yet in widespread use.

Some take this even further. Earlier this year, eight people were arrested in New York for cloning cards and hacking bank systems to raise each card's account limit, before withdrawing nearly $45 million from ATMs around the world.

Distract with a DDoS

Bank robbers can knock out CCTV and disable alarms before they break into the bank. The electronic equivalent is a distributed denial of service attack (DDoS), in which large volumes of network traffic hammer a bank's systems, giving criminals the cover they need. "While the bank's IT staff is scrambling to keep its servers online and running, criminals are transferring money from users' accounts," says Kolsek. Last year the FBI warned that criminals could get their hands on millions using software costing just $200. **Jacob Aron** ■

Technicolour piano helps you play like a pro

AFTER enduring childhood lessons, it's no surprise many of us give up playing the piano. A technicolour projection screen might put the fun back into learning.

The Projected Instrument Augmentation system (PIANO) was developed by pianists Katja Rogers and Amrei Röhlig and their colleagues at the University of Ulm in Germany. A screen attached to an electric piano has colourful blocks projected onto it that represent the notes. As the blocks of colour stream down the screen they meet the correct keyboard key at the exact moment that each one should be played (watch at bit.ly/pianolight).

A thin line between each block and the key to be pressed gives the player warning of which note is coming next. Quirks in the lines – such as ripples – advise when to add ornamentations, such as a trill. Each note block is coloured according to which finger should play it, to help improve technique, while the system highlights incorrect notes played in red.

"We had quite a few novices use it who were very sceptical at first, but then were really impressed by how quickly they could play relatively well," says Florian Schaub, who presented the system last month at the UbiComp conference in Zurich, Switzerland. Paul Marks ■

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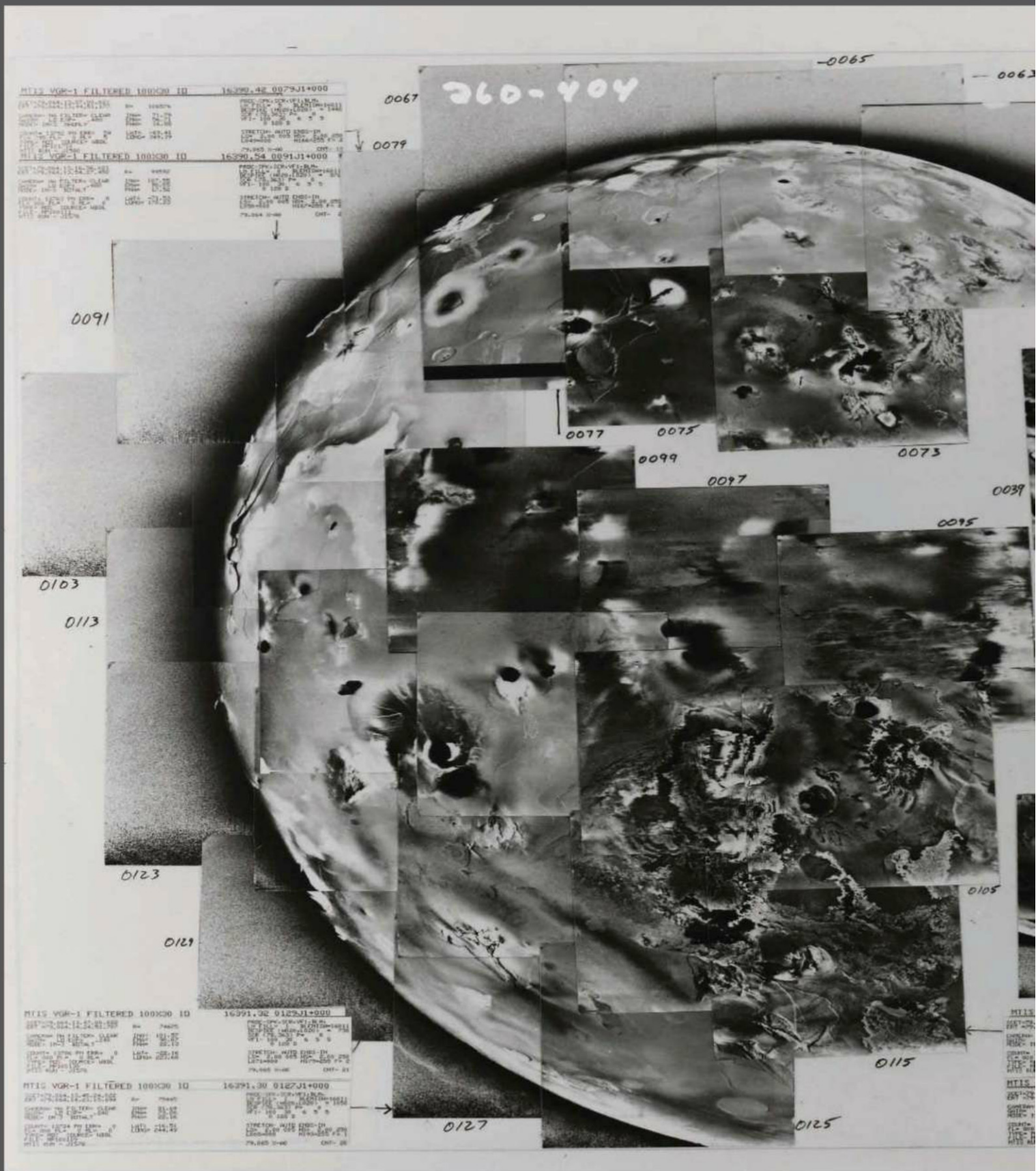
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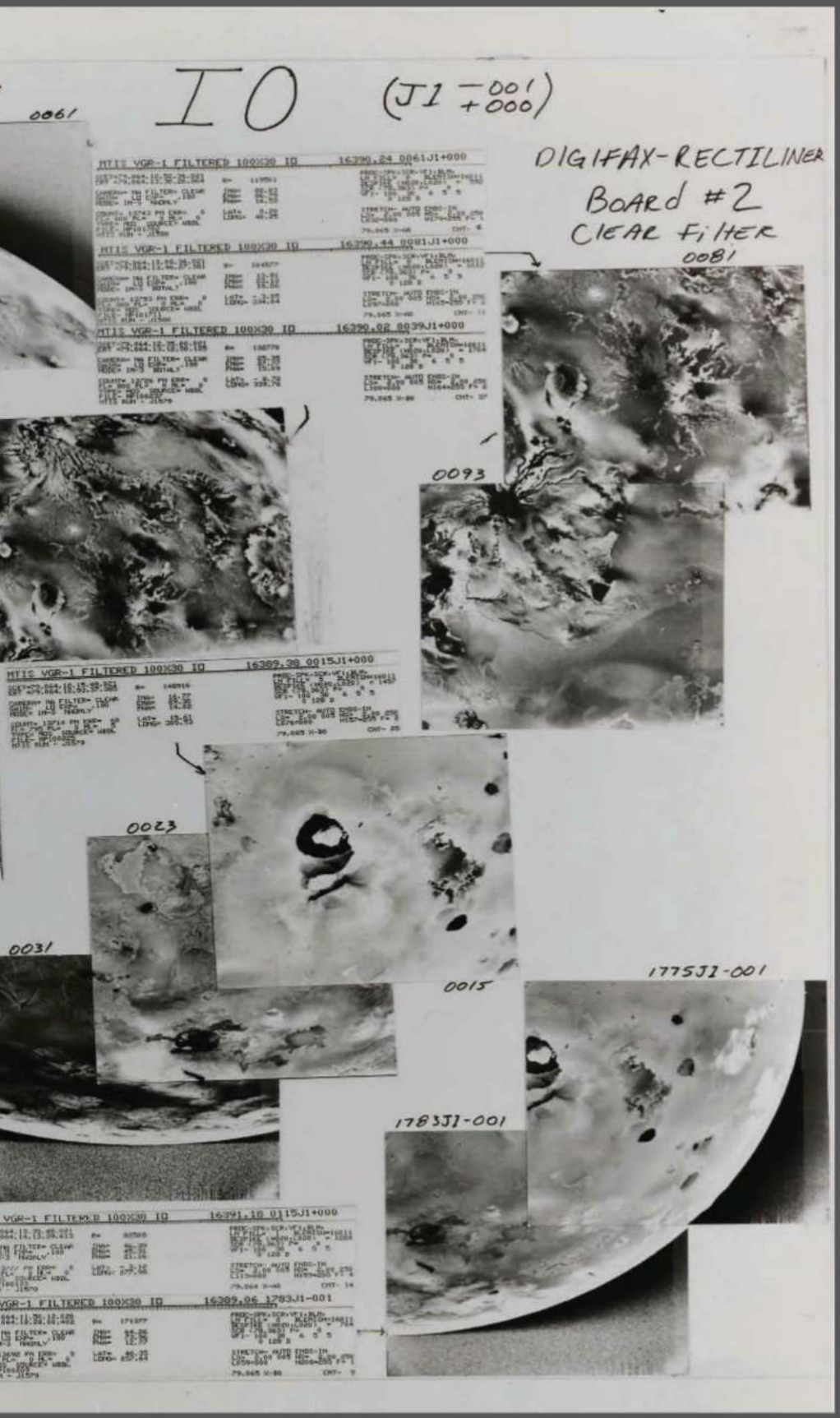

A world on fire

WE THOUGHT we knew the solar system. Apart from Earth, all the worlds out there were dead lumps freezing in the blackness of space. But when Voyager I started beaming back images as it flew by Jupiter's moon Io in 1979, something wasn't right.

For one thing, its surface was too young – nothing like the antique landscapes of our moon or Mars, whose craters date back billions of years to the early days of the solar system. There were strange pock marks interspersed among smooth plains and mountains that jutted higher than Everest, but they looked more like open sores on a world that could not heal.

There was no Photoshop back then, so scientists assembled the jigsaw of images by hand as they arrived from the distant probe (which recently left the solar system… honest!). Though primitive by the standards of the full-colour visuals brought to us by later probes, they allowed scientists to watch volcanic eruptions as they happened. It was smoking-gun evidence: after billions of years out in the cold, Io was more than still warm – it was seething with volcanic activity.

The reason for this is Io's unique position in the Jovian system. It sits closer to Jupiter than any of the other large moons. Here, tugged and flexed by the planet's huge gravitational pull, as well as that of the more distant moons Europa and Ganymede, friction keeps Io piping hot. Michael Reilly

Photograph

UCL/NASA

Scaring ourselves stupid

Overzealous suppression of disease research because of a fear of bioweapons makes the world less safe, not more, says **Debora MacKenzie**

IT IS autumn in the northern hemisphere. Somewhere in Asia, a winter flu virus is evolving that will make millions miserable in a few months. Other microbial threats are less predictable: a deadly new virus called MERS, two kinds of emerging bird flu, and a planetful of other evolving infections.

We have a fighting chance against these microbes – as long as scientists can study how they spread and kill, and find ways to stop them. So it is appalling that some researchers in Europe may have to stop because of a decision by a Dutch court, motivated as much by fear of scientists as of the germs they study.

Remember the ruckus last year, when virologists found mutations that make H5N1 bird flu airborne? I tracked that story from its announcement through an unprecedented ban on publishing the work, because US security experts feared it would hand bioterrorists a lethal weapon.

Virologists retorted that the wild virus posed a far greater threat and publication was essential to fight it. Eventually the research was published.

One of those virologists, Ron Fouchier at Erasmus Medical Center in Rotterdam, had to wait an extra eight weeks for his paper to see the light of day. Why? The Dutch export control agency insisted that he had to apply for an export licence in order to send the paper to a foreign journal, in this case *Science*.

All industrialised countries have laws controlling things that can be used to make weapons as well as for benign purposes. An export control officer must approve the export of such stuff, as well as any instructions for making it.

Fear of biological weapons means pathogenic organisms are included. The EU applies export controls to 102 human, animal and plant pathogens, and also to any genetic sequence that makes them nastier.

Crucially, there are no controls on information that is already in the public domain, or on basic research "not primarily directed towards a specific practical aim". Both of these exemptions should have applied to Fouchier's work. But the Dutch authorities insisted that they didn't, and ordered him to apply for an export licence, which was eventually granted.

Fouchier appealed the need for this, but last week the highest Dutch court for export controls rejected his appeal.

The summary of its judgement seems a near-comic portrait of legal minds baffled by science. The research created an airborne H5N1, which the court deemed a "practical aim", not basic research – as though Fouchier intended to use the virus,

"The summary of the court judgement seems a near-comic portrait of legal minds baffled by science"

not understand it. And the techniques, while public, were combined to obtain a new result – which the court decided made them novel. QED: no publishing without an export license.

What is not comic is that this judgement now applies in all 28 countries of the EU, says Fouchier. In theory, every lab in the EU working with any of those 102 microbes could now need permission to publish their research from export officers with no scientific training.

Misgivings about this aren't just scientific snobbery. Erasmus's lawyers presented the court with eight publications about four of the listed pathogens and asked them which they would withhold. They chose six. Worse, says Fouchier, they would have allowed the only one the researchers themselves deemed dangerous – because, the court said, it contained no gene sequences. In fact it was packed with links to GenBank, the main sequence database.

Fouchier says the ruling threatens freedoms of speech and the press – and a hard-won global agreement to share flu viruses and research that allows us to monitor evolving strains. Worse, if work on these organisms might not be publishable, researchers will work on something else.

The Europeans aren't alone. Last year Australia passed a bill subjecting research publications on similar pathogens to approval by the Defense Department. However, it has suspended the law while a panel, which includes researchers, studies

possible modifications.

The Dutch ruling is likely to be appealed to the European Court of Justice. That won't just mean correcting some lawyer's poor grasp of biology. The Dutch court's full decision shows the underlying issue has not been resolved. Fouchier's paper could permit production of H5N1 "as a weapon", it says, while researchers cannot self-regulate: the stakes are too high, and the conflicts are obvious.

Indeed: some researchers can go too far. Such research is already subject to stringent safety rules. Countries could improve that, and do more precautionary risk-benefit assessments.

But governments must concede that bioterrorism has happened rarely, if ever – while the threat of natural pathogens is real. We need this research. Can we not address these risks without handing control of its publication to non-scientists whose instincts are to suppress everything?

That same EU law bans the export of precursors for chemical weapons. Even so, the UK exported 4150 kilograms of precursor for the nerve gas sarin to Syria after 2004. The UK says it wasn't used for sarin. We shall see: chemical weapons treaty inspectors are heading for Syria.

There is also a treaty banning biological weapons. It was supposed to have verification and inspectors too, but that was torpedoed by US ideologues in 2001. Could that idea not be resurrected to impede work on bioweapons without killing research?

The Dutch court was trying to keep the world safe. But it inadvertently put us at greater risk, by hampering the one real defence we have against diseases and bioweapons: research. That research is itself sometimes scary, and we need to control it. But we also need to do it. ■

Debora MacKenzie is European correspondent for *New Scientist*

ONE MINUTE INTERVIEW

A crush on ivory

Biologist **Richard Ruggiero** explains how plans to destroy 6 tonnes of illegal ivory will deter poachers and traffickers

PROFILE
Richard Ruggiero is chief of the Africa branch at the US Fish and Wildlife Service and has worked with elephants and ivory for more than 30 years. He is an advocate for the illegal-ivory crush, scheduled for 8 October

What is the purpose of the ivory crush?
Increasing demand for ivory is driving uncontrolled elephant poaching. We intend to crush about 25 years' worth of ivory, confiscated by our law enforcement agents. By destroying it in this public way, we're sending a clear message to criminals who engage in trafficking and poaching that the US government takes the issue of illegal ivory trade very seriously.

How significant a threat does this illegal trade pose for elephants?
There are several reasons why elephants are having problems. Bushmeat was the driving force behind poaching in central Africa for a couple of decades. Then increasing demand from rising economies in Asia began driving this recent increase in poaching for ivory. Now, the ivory trade is by far the number one problem. Bushmeat is number two, followed by habitat loss due to conflict between human and elephant interests.

Why not flood the market with legalised ivory to satiate demand?
We feel that is absolutely not the way to go. To begin with, demand is frequently stimulated by availability. Also, in principle a legal trade makes sense, but in reality it creates a smokescreen for laundering illegal ivory. When people see a logo or statement that it was legally acquired, they don't dig very deeply for the details used to determine that. Finally, a simpler reason is that the demand is so high right now that there are not enough elephants left in the world to produce enough legally acquired ivory to satisfy the market.

What is the value of those 6 tonnes?
That depends on the type of ivory. We're mainly talking about African elephant ivory because Asian elephant ivory is very rare. African savannah elephants produce somewhat softer, yellow ivory. African forest elephants' ivory is pink, harder, straighter, and much more highly prized for carving and aesthetic beauty. The type, quality, thickness and length all play into determining its value. That said, reports indicate that ivory runs between $1000 to $2000 per kilogram.

Other countries have destroyed their ivory stockpiles. Did they inspire action by the US?
Some countries with large amounts of ivory frankly have a problem storing it, because it can be stolen and it takes up a lot of space. But mostly, destroying it is more about making a statement, and in that sense our motivations are very similar. Last year, Gabon burned and crushed a bunch of ivory, and Kenya has done it on two occasions. We're taking a slightly higher tech approach but with the same end in mind.

How will the ivory be crushed, and what will happen to it afterward?
We're using a stone crusher to reduce it to shards less than a quarter of an inch in size, which will render it commercially useless. Then, it will go back to storage as we're still deciding what to do with it. It could be interesting to get suggestions from the public. Perhaps it might make a good aggregate for concrete, bricks or statues that could be embossed with a conservation message.

Interview by Rachel Nuwer

USFWS

A world revealed

When someone unveiled the beauty of mathematics for **Edward Frenkel** as a child, it changed the course of his life. He tells **Jacob Aron** why he wants to do the same for others, and calls on his peers to take a stand against misuse of maths

PROFILE
Edward Frenkel is a mathematician at the University of California, Berkeley. His new book is *Love and Math: The heart of hidden reality* (Basic Books)

What is wrong with the way most of us are introduced to maths?
The way mathematics is taught is akin to an art class in which students are only taught how to paint a fence and are never shown the paintings of the great masters. When, later on in life, the subject of mathematics comes up, most people wave their hands and say "Oh no, I don't want to hear about this, I was so bad at math". What they are really saying is, "I was bad at painting the fence".

So what is it really like to be a mathematician?
You don't discover something beautiful every day. Most of the time, you work on something for weeks or months, only to realise that it doesn't work. But, you never give up, you go back and try to analyse the data that you have, and try to see the analogies and connections to try to come up with a new hypothesis. Then you try to test that.

What is the ultimate goal of all these efforts?
Another analogy is solving a jigsaw puzzle. Imagine that somebody gives you a puzzle, but they don't give you the box, just the pieces. You take those different pieces and try to put them together to create something of value, something beautiful and powerful. You can think of mathematics as the grand project of building this enormous jigsaw puzzle, with different groups of people working on different parts. Then, every once in a while, somebody finds a bridge between two parts, a way to assemble pieces together so that big chunks of the puzzle connect.

You work on the Langlands programme, which aims to discover those connections. Why do we need them?
From the outside, mathematics might look like one big lump. In fact, it is a huge subject which has many different sub-fields: algebra, number theory, analysis, geometry and so on. In the world of mathematics, they look like disconnected continents. But the Langlands programme connects different fields and, by doing so, tells us something about the unity of mathematics. It offers a glimpse of something beneath the surface which we don't understand.

It also reveals links between abstract maths and the structures in physics. Could the entire universe be based on maths?
I believe that physical reality as we know it and the world of mathematical ideas are two separate worlds, and neither can subjugate the other. For example, we talk about the standard model of physics, which has been very successful in predicting a whole range of phenomena. Of course, the discovery of the Higgs boson last summer was a big trial for the standard model. But from a mathematical perspective, it is just one of a tremendous class of models. We don't observe the others in our reality, but do they exist? Well, one can argue that they do in the ideal world of mathematics.

How well does this ideal world connect to our real, physical universe?
Sometimes you have some beautiful mathematics which comes out of the real world. We all know the story of Newton, an apple falling on his head. But another possibility is that within the narrative of mathematics, he discovered something about the real world. So, there is a sort of back and forth connection between the two. Neither controls the other. I think that the way to make progress in physics is to use this connection, to use experiments, but also to use the awesome powers that mathematics gives us, to come up with new ideas. And that, I think, is a good illustration of this subtle interplay between the physical and the mathematical worlds.

"Mathematics has the power to affect millions, to change the course of history"

You were fascinated by maths and quantum physics from an early age. How did growing up in Soviet Russia influence your pursuits?
By the time I was 16 years old, I was very passionate about mathematics. Just a couple of years earlier there was someone in my life,

Photography: Timothy Archibald for *New Scientist*

a professional mathematician, who opened the world of mathematics to me, this magic, beautiful universe. He did for me what I now hope to do for other people with my book.

But then there was a seemingly insurmountable obstacle. Because of some absolutely stupid policies of anti-Semitism, I was not accepted into university. The doors were closed in front of me.

Yet you managed to carry on your studies?
My career in mathematics, even much more perhaps, was saved by the generosity of my teachers – at the institution where I ultimately studied but also outside it. In some ways, I suppose this made me stronger, but I was lucky. I feel that I owe it to others to extend the same kind of help and maybe try to open doors, give access, the way I was given access.

You have previously tried to convey the beauty of mathematics through film. Why?
So much damage has been done in terms of the way mathematics is misunderstood by our society. It has essentially become impossible to talk to most people directly about it. With the film *Rites of Love and Math*, which I made four years ago with the French director Reine Graves, the idea was to penetrate some of those defences – to talk about math indirectly by appealing to the emotional, rather than to the cerebral.

In the film, we show a formula being tattooed onto the skin, becoming part of the body, and we hoped that this would allow the viewer to think about mathematics differently. The best reward was when somebody from the audience would raise their hand and ask, "But what does the formula mean?", which was exactly the point.

Do people really need to know about these formulae, if they aren't mathematicians?
We have to realise the power of mathematics. By now it's well understood that the global economic crisis was caused, in part, by misuse of mathematical models. People who understood those models were actually sounding the alarm. It was the executives who had the power, who were the decision-makers, who did not understand how these formulae functioned. Their logic was "well, while these things work we're making profits".

Recent revelations about the NSA also show how maths, particularly cryptography, can be misused...
I think it's very similar to the dilemma that physicists faced when they realised the power of the nuclear bomb. We are talking about a group of physicists who were just trying to understand the structure of the universe, the structure of matter, and inadvertently discovered this incredible power.

I would not tell any scientist to stop their research because it might have some possible evil applications. But once you discover that it does have these applications, I think it's also your responsibility to do whatever you can to prevent the discovery from being used for evil purposes.

So mathematicians should take a stand?
Mathematical power is not the power of a bomb. You cannot see its effect as immediately as Hiroshima and Nagasaki. But a formula can be just as powerful in terms of controlling our lives. It can alter the course of history, it can affect millions of people.

I think we mathematicians are a little bit behind the curve, we are not fully aware of the Frankenstein which we may have already created or could create. I think that's another aspect of this responsibility of mathematicians to take a more public role – to educate the public by giving them access to the beauty and power of mathematics.

Premature anti-age

From Tom Vulliamy, Senior Lecturer in Molecular Biology, Queen Mary, University of London
You report a study which found that telomere length increased in a group of 10 men with prostate cancer, who followed a healthy-living regime including a meat-free diet, exercise and yoga (21 September, p 14). But it is important to highlight the limits of these results. It was a small pilot study and the significance of the effect of these lifestyle changes on telomere length is actually quite borderline: only two or three men showed clear improvement over what can be seen in the control group.

I'm going to wait to see whether this can be replicated on a larger scale and with more sizeable effects before I get excited.
London, UK

Me medicine

From John Cantellow
Donna Dickenson writes about the threat to communal health measures posed by the growing demand to fund personalised medicine (14 September, p 26). Most patients expect that the medicine the doctor prescribed will treat the condition they are diagnosed with. The reality is, however, that the effectiveness of many licensed pharmaceuticals is measured in percentage points over that of placebos.

Consequently, many patients are exposed to potential side effects with no prospect of benefit. "Me medicine" enables better targeting and hence helps to bridge the gap between reality and patients' expectations.
Derby, UK

Unlearned Abbott

From Jock Webb
Alas, your mention of our new Australian prime minister Tony Abbott does not even scratch the surface of his scientific ignorance (14 September, p 6). As well as his notorious comment that "the climate change argument is absolute crap", he has suggested that carbon dioxide is weightless and thus very hard to measure. He has compounded his party's almost unbelievable science phobia by selecting the first ministerial team in 80 years to have no person responsible for science. He has, of course, selected a minister for sport.

As a school science coordinator and member of a family where science was and is considered of great importance, I may have to resort to products resulting from the sophisticated distillation of fermented liquors to avoid despair.
Narromine, New South Wales, Australia

Indo-European roots

From Dewi Jones
Russell Gray and Quentin Atkinson propose that a proto-Indo-European language arose in Anatolia 9000 years ago and spread out from there together with farming (7 September, p 32). I don't really understand their method, but there are one or two points I can raise from what I know of the history of Indo-European languages.

Your map shows an Indo-European language arriving in Britain about 3000 years ago. Didn't farming arrive in the Neolithic, well before 1000 BC?

I read that the reconstructed proto-Indo-European resembles Lithuanian and Latvian more than any other language. That suggests an origin nearer the Baltic than Anatolia – somewhere in the Ukraine, according to the anthropologist and archaeologist Marija Gimbutas. She describes barbarians from the Ukraine conquering in all directions and leaving burial mounds behind. The Celts, whose culture arose somewhere in central Europe – likely enough from those "Ukrainians" – arrived in Britain early in the first millennium BC.
Aberystwyth, Ceredigion, UK

Unconscious wishes

From Richard Jones
I found Sara Reardon's article on accessing the mind of someone with severe brain injury utterly terrifying (24 August, p 14). It is a significant but tiny step to discover that patients who are minimally conscious or in a persistent vegetative state still recognise their names.

But how can anyone with the slightest touch of compassion go on to say that, if development of the technique enables us to learn more about what they are really thinking, we need not necessarily take their thoughts into account because they may be "depressed or not emotionally healthy" and their state of mind may be "clouding their judgement"?
West Linton, Peeblesshire, UK

Just like us

From Charles Merfield
I was puzzled by the idea that the machine-learning approach to artificial intelligence based on statistical analysis of big data sets was "not like us" (10 August, p 32). If there is a form of AI that is not like us, I would say it is the logical rule-based system, which appears to be based on the erroneous Enlightenment idea of humans as rational beings. We increasingly discover how supremely irrational humans can be.
Lincoln, Canterbury, New Zealand

Smoked out

From Nicholas Taylor
There is a simple solution to issues raised by a possible Europe-wide ban on the sale of e-cigarettes

Enigma Number 1769

Crossing lines

IAN KAY

I have drawn a number of straight lines across a large sheet of paper, each extending from edge to edge on the paper, so that each line crosses all the other lines. One of the intersections is between three lines, all the others are between just two lines, and none of them are on the edge of the paper. I counted the number of non-overlapping areas formed that did not touch the edge of the paper and found that this was exactly three times the number of non-overlapping areas that did touch the edge of the paper. How many lines did I draw?

WIN £15 will be awarded to the sender of the first correct answer opened on Wednesday 30 October. The Editor's decision is final.
Please send entries to Enigma 1769, New Scientist, Lacon House, 84 Theobald's Road, London WC1X 8NS, or to enigma@newscientist.com (please include your postal address).
Answer to 1763 Clever spells: Eve and Oddy's numbers are 378 and 201
The winner Bill Payne of Woking, Surrey, UK

from 2016, unless they have been approved as pharmaceuticals (14 September, p 6). We could ban smoking in all public places now; ban the public sale of cigarettes within six months (allowing mail order under plain cover only) and promote e-cigarettes as an aid to quitting.

It's certainly possible to quit in two years. By 2016 hardly anyone will be smoking anyway. Then you can ban e-cigarettes, except on prescription.
Little Sandhurst, Berkshire, UK

Precise time

From G. John Dick
Thank you for the report on the new, more precise atomic clock using emissions from ytterbium atoms (31 August, p 15). Readers may be interested to know which technical advance made such a level of stability possible.

For some time now the performance of the very best atomic clocks has been limited, not by the statistics of photon emission by the atoms themselves, but by instabilities in the laser that "interrogates" the atoms, leading to "aliasing" effects in the detected signal. The recent improvement is primarily due to advances in the performance of the interrogating lasers (arxiv.org/pdf/1305.5869).

The authors propose that even higher stability can be achieved by using two atomic systems with overlapping cycles, which would virtually eliminate the aliasing (also known as the "Dick effect"). Of course, it is only with the advent of the ultra-stable ytterbium atomic system that these statistical fluctuations become of much consequence: before then they were minor compared with those of the signal being detected.
Claremont, California, US

Refugee record

From Will Podmore
You quoted the UN High Commissioner for Refugees as saying that the war in Syria was generating the "biggest displacement crisis of all time" (14 September, p 8). This is untrue.

In 1945, when the Nazi regime was defeated, the number of its former forced labourers exceeded 6 million. Another 4 million people were displaced by the war. Between March and September 1945, around 10 million refugees and displaced persons were repatriated.
London, UK

The editor writes:
■ Also, estimates of the number of people displaced in the partition of British India in 1947 range from 10 to 15 million.

Photons in flatland

From Christopher Dean
I have also thought along the same lines as reader Lerida Arnold, that entangled photons aren't in some sense actually divided, even though we view them as such (17 August, p 30). But it is not necessary to invoke extra dimensions on their behalf.

Imagine that we coalesce the Cartesian x, y, z axes into one, leaving a "space-time" in two dimensions: space and t. Considering the relatively peculiar nature of light, it is possible that photons may indeed not recognise one of these "dimensions", either "space" or "t". In that case, entangled photons are actually still coalesced on that axis.
Hobart, Tasmania, Australia

Light comes first

From Dave Howells
In his letter, Wilken Sporys reflects on the idea that for an object "travelling" at the speed of light, space and time are effectively zero (31 August, p 31). Sporys concludes that time and space only emerge as an object slows below the speed of light.

That thought poses questions, such as what do we mean by the speed of light? And what does it mean to slow down? I wonder whether it might be more productive to regard space and time arising from what light does, rather than consider light travelling within space and time?
Gowerton, Swansea, UK

Family planning

From Frank Siegrist
The argument that people in developed countries who desire more children will become more numerous with each generation, although making sense superficially, seems a bit naive (14 September, p 31). Grass with legs could run away from cows; all grass should have legs by now; yet

I still haven't seen grass with legs.

People are programmed to want sex, and that's how children arrive. Furthermore, once the children are here, we are programmed to take care of them. If we look at it this way, humans should have died out with the invention of contraception. This didn't happen, so apparently we still miss children if they don't appear spontaneously, and that's why we plan them. So how many do we plan? One child might be lonely, so the answer must be two.

Is there an inborn tendency in some people to want more children? Maybe, but I don't think so. Most third children I know of were "accidents".
Lausanne, Switzerland

Warning: humour

From Alan Carter
Surely, in the interests of health and safety, signs like the one highlighted by Feedback on the Australian beach reading "WARNING: Water" (13 July) should have an adjacent sign reading: "WARNING: delegating your ability to assess risk to writers of warning signs can be bad for your health".
Aberdeen, UK

Ave Maria!

From Liesel Smith
You referred to "the smaller Ligeia and Punga mares" on Titan (2 March, p 19). Clearly you intend a plural of *mare*, Latin for "sea". But the Latin plural is *maria* and this word isn't even half-Anglicised. If perchance our aliens speak Latin, they would feel quite at home among the *maria*.
Pretoria, South Africa

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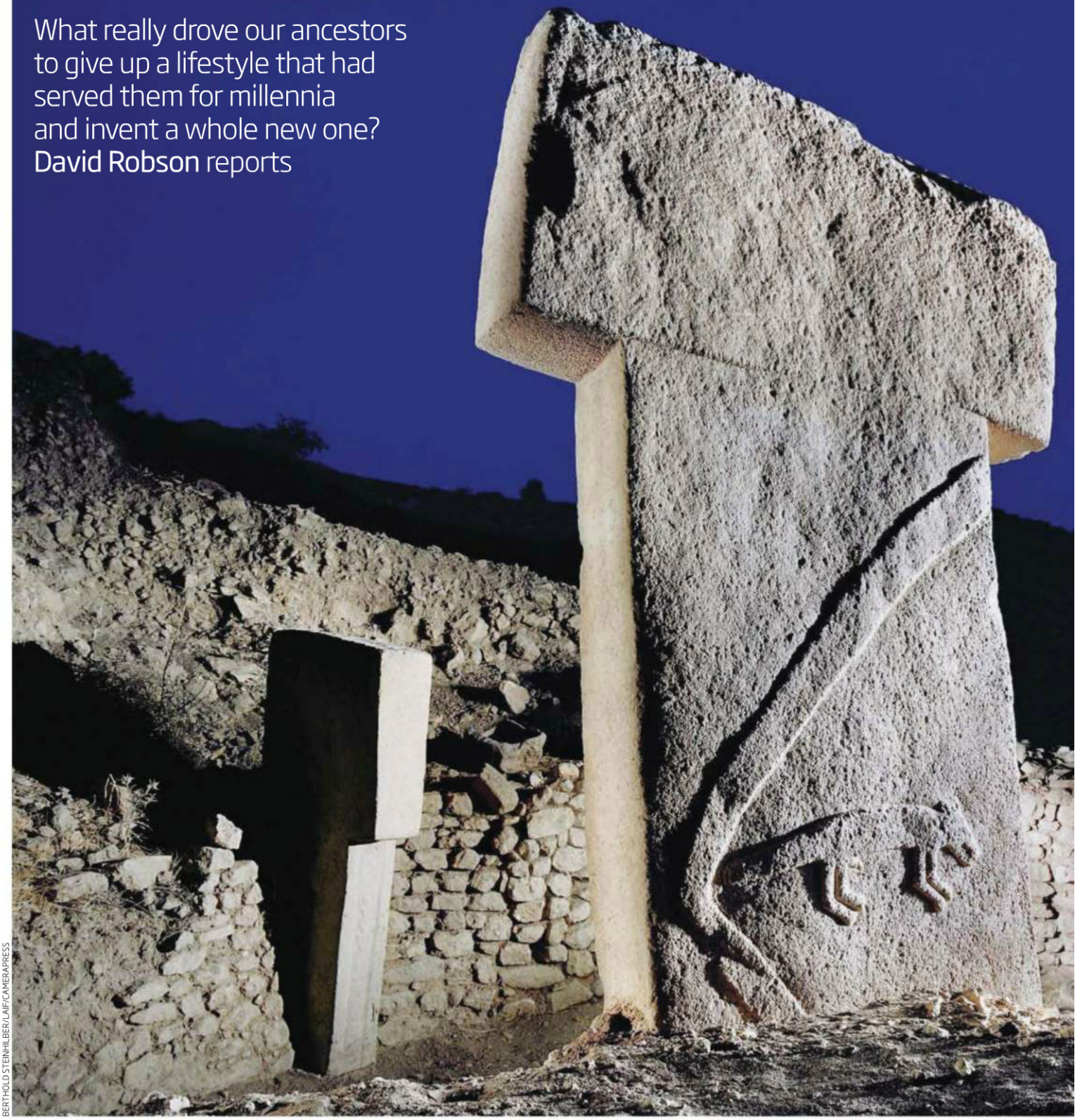
Civilisation's true dawn

What really drove our ancestors to give up a lifestyle that had served them for millennia and invent a whole new one? **David Robson** reports



BERTHOLD STEINHILBER/LAIF/CAMERAPRESS

Göbekli Tepe: the world's first temple in southern Anatolia

WHEN Steven Mithen's team began to dig through the desert soil, his expectations were low. "We thought it was just a big rubbish dump," he says.

Still, even the prospect of rifling through trash was cause for some satisfaction. Mithen, an archaeologist at the University of Reading, UK, initially raised a few eyebrows when he told colleagues of his plans to dig for Stone Age ruins in south Jordan. "They said we'd never find anything there – it was a backwater," says Mithen. He proved them wrong by finding the remains of a primitive village. By sifting through its rubbish, he hoped to gain a glimpse of day-to-day life more than 11,000 years ago.

But as they dug through the detritus, one of his students came upon a polished, solid floor – hardly the kind of craftsmanship to waste on a communal tip. Then came a series of platforms engraved with wavy symbols. The excitement grew. "We were staggered day by day to find it getting larger, more complex, more peculiar," he says. "I'd never seen anything like it before. It was literally a moment when all your ideas change."

Mithen now compares the structure to a small amphitheatre (see picture, page 34). With benches lining one side of a roughly circular building, it looks purpose-built for celebrations or spectacles – perhaps feasting, music, rituals, or something more macabre. Pointing out a series of gullies running down through the floor, Mithen wonders whether sacrificial blood might have once flowed in front of a frenzied crowd.

Whatever happened at the place now known as Wadi Faynan, the site could transform our understanding of the past. At 11,600 years old, it predates farming – which means that people were building amphitheatres before they invented agriculture.

It wasn't supposed to be that way. Archaeologists have long been familiar with the idea of a "Neolithic revolution" during which humans abandoned the nomadic lifestyle that had served them so well for millennia and settled in permanent agrarian communities. They domesticated plants and animals and invented a new way of life. ("Neolithic" means "new stone age").

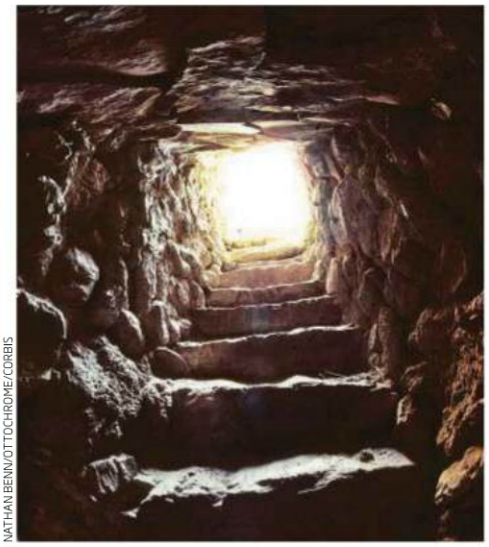
By about 8300 years ago, people in the Levant – modern-day Syria, Lebanon, Jordan, Israel, the Palestinian territories and parts of southern Anatolia – had the full package of Neolithic technologies: settled villages with communal buildings, pottery, domesticated animals, cereals and legumes. Art, politics and astronomy also have their roots this ›

TOWER OF POWER

It has been called the world's first skyscraper. 11,000 years ago, a society of hunter-gatherers built an 8-metre tall tower and staircase out of stone – for apparently no reason.

Ever since it was discovered, the Tower of Jericho has puzzled archaeologists. Some have suggested that it was built as a watchtower, but there's no evidence of any invasions. Instead, the tower might have been a way for the first villagers to bond.

Roy Liran and Ran Barkai at Tel Aviv University, Israel, recently simulated the way the tower would have looked during the summer solstice. They found that the shadows of the surrounding hills would have first enveloped the tower as the sun set, creating an image full of foreboding. The eerie effect could have been used by the village chiefs, they say, to scare their brethren into working harder.



NATHAN BENN/OTTOCHROME/CORBIS

"Instead of farming, very different motivations seem to have brought people together – things like religion, culture and feasting"

time. "It's one of the most important shifts in history," says Jens Notroff at the German Archaeological Institute in Berlin.

And yet here was a settlement more than 3000 years older displaying many of those innovations, but lacking the technology that is supposed to have got the whole thing started: farming. The people who built Wadi Faynan were not nomads, but neither were they farmers. They probably relied almost exclusively on hunting and gathering.

Instead of agriculture, then, some very different motivations seem to have drawn these people together – things like religion, culture and feasting. Never mind the practical benefits of a steady food supply; the seeds of civilisation may have been sown by something much more cerebral.

For much of the 20th century our view of the Neolithic was seen through the lens of more recent social upheaval: the industrial revolution. The idea originated, in part, with Marxist archaeologist Vere Gordon Childe. Seeing the urban societies that had coalesced around factory towers and "dark satanic mills", Childe suspected that the first farms could have been similar hotbeds of rapid social and cultural change.

Driven to extremes

He proposed that it began in the Levant around 10,000 years ago. As the ice age ended, the region became more arid, save for smaller patches of lush land by rivers. With these limited areas to forage, nomadic hunter-gathers discovered that it was more efficient to cultivate barley and wheat in one place. A baby boom followed. As Childe put it in his 1936 book *Man Makes Himself*: "If there are more mouths to feed, there will also be more hands to till the fields... quite young toddlers can help in weeding fields and scaring off birds." And as the farmers' crops and families blossomed, so too did their crafts, including carpentry and pottery, along with greater social complexity as the groups began to organise their activities around their work. The growing communities would have also been fertile ground for more organised forms of religion to flourish.

At least, that was the theory. *Man Makes Himself* became a touchstone for many archaeologists – even as cracks began to appear in some of its assumptions. Studies of the climate, for instance, suggest the changes following the ice age were not nearly as radical as Childe believed. Without the environmental spark, there were doubts that agriculture offered any real benefits. Particularly when you only have a few bellies to fill, plundering nature's larder is just as efficient as the back-breaking business of planting, weeding, and harvesting. So why change?

By the 1990s, those cracks had turned to gaping chasms, following digs in Anatolia, Turkey. The region was already attracting attention for a site known as Nevali Çori, which was around 10,000 years old. Although it seemed to be a simple settlement of proto-farmers, the archaeologists also uncovered signs of more advanced culture, embodied in a series of communal "cult buildings" full of macabre artwork.

The buildings were remarkably large and complex for something so old. And what they

STEVE MITHEN

contained was even more revealing. In one sculpture, a snake writhes across a man's head; another depicts a bird of prey landing on the heads of entwined twins. The most eye-catching feature was a collection of strange, anthropomorphic T-shaped megaliths with faceless, oblong heads and human arms engraved on their sides. As people sat on benches around the walls of the buildings, these monuments must have loomed over them like sentinels.

Lost society

Sadly, the site was submerged when the Atatürk dam was built across the Euphrates. But one of the archaeologists, Klaus Schmidt, set about scouring the surrounding countryside for further clues to the origins of this lost society. During this tour he found himself on a mound called Göbekli Tepe. The grassy knoll was already popular with locals visiting its magic "wishing tree", but what really caught Schmidt's eye was a large piece of limestone that closely resembled those T-shaped megaliths from Nevali Çori.

It didn't take him long to realise he had stumbled on something even more extraordinary. Buried beneath the hill, he found three layers of remains. The oldest and most impressive was more than 11,000 years old, with a labyrinth of circular "sanctuaries" measuring up to 30 metres in diameter. Around the inner walls were magnificent, T-shaped monuments encircling two larger pillars, like worshippers surrounding their idol. "They appeared to be everywhere," says Notroff, one of Schmidt's colleagues.

Some were engraved with belts and robes, and given their monumental size – around three times the height of a modern man – and abstract appearance, Schmidt interprets them as representing some kind of god-like figure. Others bear grotesque carvings of wild beasts such as snakes, scorpions and hyenas. To Schmidt, the images bring to mind the horrific scenes in Dante's *Inferno*.

If Nevali Çori was a humble parish church, then this was a cathedral. Strangely, each sanctuary seems to have been dismantled and deliberately filled in some time later – perhaps as part of a ritual. Amid the jumble of debris, Schmidt's team have found many bones, including human remains. His team has also found a surprisingly high number of rooks and crows – birds that are known to be drawn to corpses. For this reason, Schmidt's team believe that some of the buildings' functions may have centred on death.

We can never know what happened there, but Schmidt has some suspicions. From the outset, he was fascinated by strange door-like "porthole stones", found within the sanctuaries and often decorated with grisly images of predators and prey. Since the holes in the middle are often the size of a human body, Schmidt imagines that visitors may have crawled through to symbolise the passage into the afterlife.

It is clear that Göbekli Tepe was the creation of a sophisticated society, capable of marshalling the labour of perhaps hundreds of people. "It suggests organisation and cooperation," says Notroff. "That degree of social complexity just wasn't expected in emerging early Neolithic cultures."

Along with the complex artwork and intricate ideology, this kind of development was supposed to come long after agriculture. Yet Schmidt failed to find any signs of farming. Domesticated corn can be distinguished from its wild ancestor by its plumper ears, but there was no trace of it. Stranger still, there is no sure evidence of any kind of permanent settlement at Göbekli Tepe. Schmidt says it was too far away from water supplies and he has found little evidence of the hearths, fire pits or tools you might expect in a dwelling.

His conclusions were radical. He proposed that Göbekli Tepe was a dedicated site of pilgrimage, perhaps the culmination of a long tradition of gatherings and celebrations. Importantly, it was ideology, rather than farming, that was pulling these people together to form a larger society.

Indeed, it may have been the need to feed people at these kinds of gatherings that eventually led to agriculture – which turns the original idea of the Neolithic revolution on its head. "Rituals and feasts may have been the impetus to motivate people to gather on certain occasions at certain places," says Notroff. "Maybe, new food sources and processing techniques were explored to feed this demand." Tellingly, recent genetic work pinpoints the origin of domestic wheat to a spot very close to Göbekli Tepe.

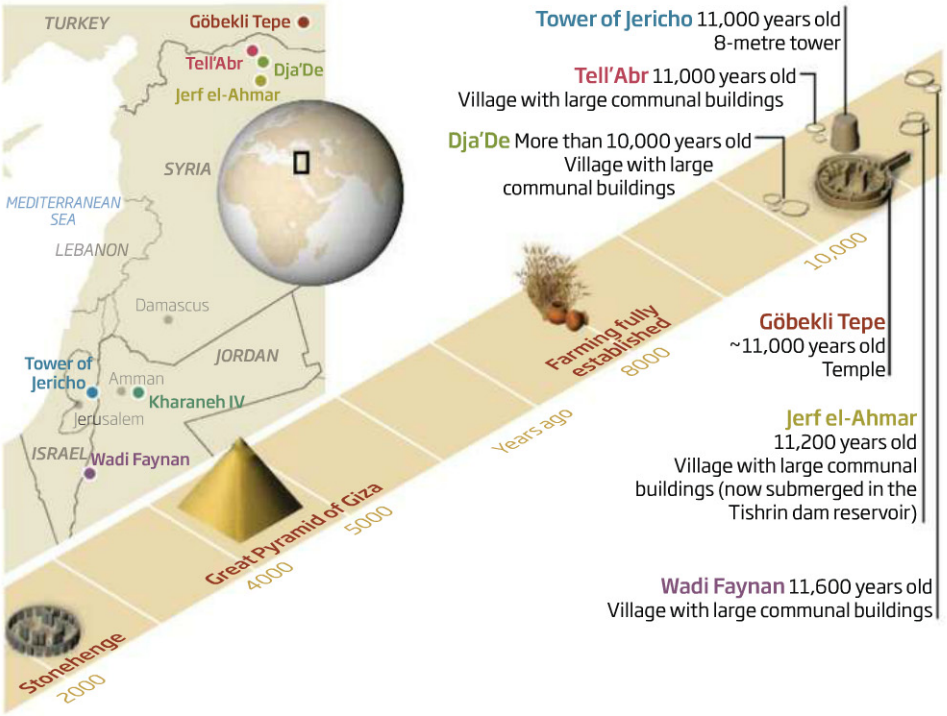
Alternatively, agriculture could have been an accidental by-product of social gatherings where large quantities of wild food plants were consumed and their seeds dropped, creating a cycle of unintentional cultivation. "My guess is that domesticated plants fall out almost by accident, due to intensive exploitation of wild plants that is demanded by the communal activities," says Mithen. Some researchers now argue that domestication of animals, particularly wild cattle, also has spiritual rather than economic roots (see "Sacred cows", page 36).

Schmidt's finds astonished archaeologists and captivated the wider world. The "first temple" soon began attracting a new swarm of pilgrims, with film-makers, archaeologists and tourists flocking to visit. "It was extraordinary," says George Willcox of the Archéorient Laboratory of the French National Centre for Scientific Research in Jalès, who has visited the site. "People just couldn't believe it was Neolithic."

Some researchers are dubious. The original peoples' habit of periodically burying their ›

Monumental discoveries

Recent finds in the Levant suggest that people were living in large settlements and building temples long before they invented agriculture



The "amphitheatre" at Wadi Faynan: evidence of monumental architecture 11,600 years ago

SACRED COWS

Domestication of plants in the Neolithic Middle East is often explained in economic terms, as a labour-saving device or an attempt at food conservation. In the light of new finds (see main story) , this long accepted explanation is no longer convincing.

It now appears that the human mindset began to change before the economy changed. It began with nomadic hunters and gatherers coming together for ritual purposes at places like Göbekli Tepe. As some laboured, probably seasonally, on the construction of the monuments, others gathered wild grains to feed them. Some grain dropped near the temporary settlement. By a process of repetition and gathering the nearest plants first, wheat was gradually and accidentally domesticated.

What of animals? Could "accident" have played a role there too?

We argue that the domestication of animals had its conceptual roots in hunter-gatherer societies of the Upper Palaeolithic (around 20,000 to 12,000 years ago). Cave art suggests that people at that time had settled on a bestiary of species with special significance beyond pure economics.

The core species of Upper Palaeolithic art were aurochs, horses, bison and felines. Other species, such as mammoths, were added and discarded in some areas, but there was never a time when Upper Palaeolithic cave artists painted whatever took their fancy, such as predominanty human faces, trees, or hares. The image-makers focused on creatures that were believed to be spiritually powerful in some way.

What we call "conceptual domestication" of certain – largely herd – animals was already part of people's thinking long before they began to drive and corral actual animals.

We still see this in modern foraging societies such as the San of southern Africa, where the social status of "ritual specialists" (similar to shamans) frequently rests on their intimate relations with powerful spirit animals. Often, these animals are big cats, the ultimate, intractable wild creatures. But this sort of relationship extends to the control of economically beneficial species, such as antelope.

The striking carvings at Göbekli Tepe suggest that around 11,000 years ago, a similar "spiritual" relationship may have existed with numerous creatures: birds, felines, foxes, aurochs and even insects.

At later sites, the relationship begins to focus on more easily corralled animals, such as pigs and sheep. However, because ritual specialists find power in wild animals rather than those that have been domesticated and thereby trivialised, this trend eventually focused on herds of wild aurochs.

Possibly, people already believed that these wild herds were under the control of ritual specialists. Actual domestication, by driving and corralling, was a logical next step, as it would have been a visible manifestation of the ritual specialists' power. People did not invent domestication of animals for economic purposes: they did so for socio-religious ones.

David Lewis-Williams is founder and professor emeritus of the Rock Art Research Institute, University of the Witwatersrand, South Africa. David Pearce is the director of the Institute. They are co-authors of *Inside the Neolithic Mind: Consciousness, cosmos and the realm of the gods* (Thames & Hudson)

VINCENT J. MUSI/NGS

sanctuaries means there is always the possibility that old remains were dug up to dump on the monuments, rather than contemporary debris. That would shave hundreds or thousands of years off the age of the temple, making it much less revolutionary.

Others doubt Schmidt's claims that Göbekli Tepe was the site of pilgrimage rather than a permanent settlement. "I think the evidence is weak," says Edward Banning at the University of Toronto, Canada. Take the apparent lack of a water supply. Banning points out that rivers and springs that once watered the site may have long since dried up without leaving a trace. The extravagant artwork, meanwhile, could just be house decorations. "It's quite possible to have domestic structures that are heavily invested in symbolism," he says – just look at the way people today hang crucifixes and icons in their kitchens.

Such concerns don't necessarily derail Schmidt's broader theory that culture, rather than farming, propelled our march to civilisation. "I think there is something to be said for social and ideological changes having an important role," says Banning. But it was clear that to expand the theory, archaeologists needed to look further afield.

Ideology before subsistence

Fortunately, they were on the trail almost as soon as Göbekli Tepe was discovered. A little down the Euphrates, across the border into Syria, French researchers have found a trio of early Neolithic villages called Dja'De, Tell'Abr, and Jerf el-Ahmar. Although they are clearly permanent settlements rather than sites of pilgrimage, they all house large, highly decorated communal buildings that seem to have been the product of the same complex, ritualistic culture as Göbekli Tepe.

With Syria's civil war raging, they are now off limits – but Willcox did manage to sift through charred remains of seeds caught in cooking pots and house fires at Jerf el-Ahmar. He found that the first inhabitants were still gathering a wide variety of wild cereals and lentils. Later on, however, in the upper layers, a few species begin to dominate – ones that would later be domesticated. You also find evidence of imported crops that wouldn't naturally grow in the region. So the people of Jerf el-Ahmar were probably cultivating plants by the latter stages of its occupation. The killer point, though, is that they had begun to build their complex society long before they had domestic crops.

The "amphitheatre" at Wadi Faynan, Jordan, which Mithen first excavated in 2010, tells a similar story much further south. With a floor area of nearly 400 square metres – about the same as two tennis courts – it is one of the largest ancient structures to have been found after the Göbekli Tepe. It was also surrounded

"People were already experimenting with new ways of living 20,000 years ago"

ED KASHI/NGS

The Neolithic village Nevali Çori disappeared under water when the Euphrates was dammed

by a "honeycomb" of other rooms, which Mithen suspects may have been workshops.

Importantly, the remains are neatly layered, allowing the archaeologists to pin a firm date on the site – 11,600 years ago, right at the dawn of the Neolithic. So far, Mithen has only found wild varieties of figs, barley and pistachios in the lowest, oldest layers, suggesting the first inhabitants were hunter-gatherers.

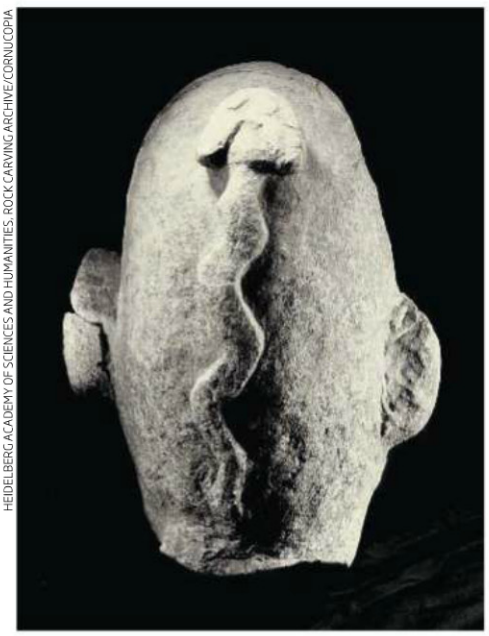
What's most surprising is that Wadi Faynan lies hundreds of kilometres from the other sites. "It shows that a complex society was developing in the wider Levant at that time," says Mithen. Further east, too, there is monumental architecture that predates agriculture and may have had a ritualistic function (see "Tower of Power", page 34). Mithen and others now think of the whole region as an area of "social experimentation".

If these finds are helping to rewrite one chapter of the Neolithic, there are still many blank pages to fill. Wadi Faynan and Göbekli Tepe must have been the product of a long journey – so when did we make those first baby steps, and why? We may have to dig deep into the past to find out. Around the banks of the Sea of Galilee in Israel and across the border in Jordan, archaeologists have unearthed the foundations of brushwood and mud huts dating from at least 20,000 years ago. From the scattering of plant remains, it seems these sites were occupied by many people, perhaps for long periods, suggesting they were already experimenting with new ways of living at this time.

As if foreshadowing the huge gatherings at Göbekli Tepe, these places were meeting points for different bands from across the region, each of which left their mark with signature styles of stone tools. And their connections may have stretched far and wide; the Jordanian site, Kharaneh IV, has yielded a small hoard of assorted seashells originating from the Mediterranean, Red Sea and the Indian Ocean. "We knew these large-scale interaction networks were common in the Neolithic period, and now sites like these clearly demonstrate these networks were established much earlier in time," says Lisa Maher at the University of California, Berkeley, who has studied the site in Jordan.

Might these early meetings have spurred on the cultural change? "In a large group you need to establish a collective identity," explains Trevor Watkins at the University of Edinburgh – otherwise the meetings are volatile and soon break up. "And the way that works is through ceremonies, rituals, and symbols." So social gatherings can fuel cultural change.

It also works the other way: culture can encourage us to seek out other people to share ideas and maintain our traditions. "It's why I live near Edinburgh," says Watkins. "We have a lot of music, theatre, writers, and from my point of view, a lot of archaeologists to talk to." There's no reason to think that the thirst to share and communicate would have been any weaker in prehistory.



HEIDELBERG ACADEMY OF SCIENCES AND HUMANITIES, ROCK CARVING ARCHIVE/CORNUCOPIA

Snake head sculpture from Nevali Çori (right), portal stone from Göbekli Tepe (left)

So perhaps the Neolithic arose as communities and cultures evolved together through a self-perpetuating cycle. It was just luck that with a lush climate and plentiful wild foods, these emerging societies could also find a new way of exploiting the land to feed their booming populations. By around 8000 years ago, they began to explore pastures new, bringing their seed, languages and genes to the rest of Europe and Asia.

For the moment, the archaeologists have their hands full exploring the riches of their digs. Schmidt's team hasn't reached the oldest layers of Göbekli Tepe yet, so it may yet yield more secrets. "To completely understand the importance and meaning of the site, a lot more research is necessary," says Notroff. And within the past few years, Turkish archaeologists have explored other, smaller sites nearby that might solve some of the remaining mysteries of the culture.

Mithen, meanwhile, finds the prospect of work at Wadi Faynan both "daunting and thrilling". It has already been more than a decade since he first visited. "And I know it's going to be a dominant aspect of my work for the next 10 or 20 years." As his team digs deeper, he hopes he may find some structures from even further back in time – perhaps helping to join the dots between those early mud huts and the more elaborate society that sat around the amphitheatre. "We've only scratched the surface."

Whatever they find, our views of the origin of civilisation – and of the modern world that we live in – will never be the same. ■

David Robson is a feature editor at *New Scientist*

Inflation handily explains how the universe expanded after the big bang. Is it all a bit too convenient? Maggie McKee investigates

Pop-up universe

IT WAS still dark and bitterly cold when Paul Steinhardt met Anna Ijjas at her office in Harvard on 21 March. They had risen before dawn to watch researchers in Paris announce the first major results from the European Space Agency's Planck satellite, which has been mapping light from the universe's infancy since 2009.

Other missions have studied this light, aka the cosmic microwave background. But cosmologists the world over were itching to find out what Planck had seen because its detectors are at least three times as sharp as those on any previous satellite. It therefore provides the best-ever portrait of the universe not long after the big bang.

Would Planck lend weight to our leading theory of a well-mannered universe that underwent a precocious growth spurt known as inflation? Or would it force us back to the drawing board to understand our cosmic past?

"The overall conclusion is that it is an extremely good match to the Planck data," announced George Efstathiou at the Paris meeting. "If I were an inflationary theorist I'd be very happy."

ALEXANDER KENT

But after reading the Planck team's paper, which went online shortly after the briefings, Ijjas reached the opposite conclusion. And soon she convinced Steinhardt and Avi Loeb, the head of Harvard University's astronomy department, that the results were troubling. "Planck has created some problems for inflation that weren't there before," says Steinhardt, a cosmologist at Princeton University in New Jersey.

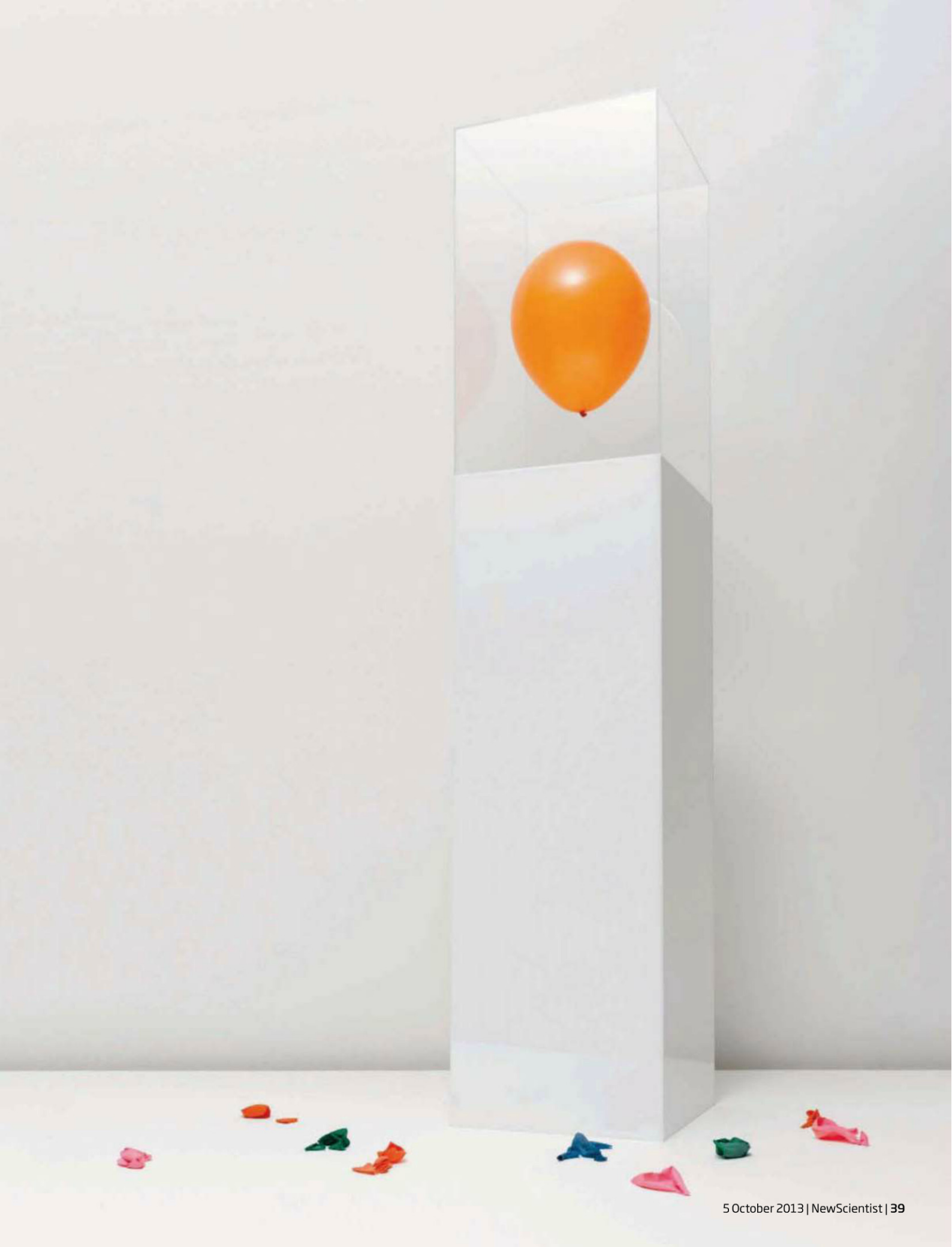
Others disagree with that conclusion. But if Ijjas, Loeb and Steinhardt are right and inflation really is in difficulties, it would spell disaster for our entire understanding of the cosmos. Either way, Planck is driving us to take a harder look at the theory.

Smooth operator

Inflation proposes that our corner of space expanded by a factor or 10^{25} or more in a tiny fraction of a second soon after the big bang. To get a sense of how incredible this expansion is, imagine the full stop at the end of this sentence growing to 1 million light years across in the blink of an eye. Yet this remarkable theory has become part of our standard picture of cosmology because it seems to elegantly account for a number of astronomical puzzles.

One is the astonishing evenness of the universe. Observations show that the microwave background radiation filling the cosmos is the same temperature everywhere to within 0.0003 °C. That's surprising because it is also true for parts of the sky that appear too far away for light to have had time to travel between them. So there is no way heat radiation could have evened out the roiling temperatures present at the universe's birth. Inflation provides an explanation – these parts of space had been in contact before inflation began, and had simply been pushed to great distances when the universe suddenly swelled up.

And yet, if the universe was identical everywhere then there would be no structures like galaxies, stars and planets. Inflation has an answer for this too. Quantum fluctuations in energy continually produced small dents in space-time. When inflation began soon after the big bang, it stretched these dents out to cosmic proportions, and they acted as nests for matter to fall into and eventually grow into the structures we see today. These nests appear as spots that are slightly warmer and cooler than the average temperature of the cosmic microwave background (CMB). They were first measured by the COBE satellite in 1992 and now by Planck in unprecedented detail. "Planck confirmed the quantum ›



origin Narromine of the universe's structure," says Slava Mukhanov of Ludwig Maximilians University Munich in Germany.

So what's not to like about the theory? Well, for one thing, it's not clear what actually does the inflating. One view is that it's caused by a quantum field associated with a hypothetical particle called the inflaton. At each point in space, the idea goes, the inflaton field has a certain strength, much as an electric field varies with distance from an electric charge.

The energy that an electric field stores is proportional to the square of its strength, a relationship that in a graph looks like a U-shaped parabola. It means that where the field is twice as strong, it harbours four times the energy. Yet the inflaton's behaviour is up for grabs. If it exists, the value of its potential energy dictated how fast space expanded due to inflation. So it must have been positive when inflation started and then dropped to zero when it ended. But how high did the energy reach, and how did it vary from inflation's start to its end? Hundreds of models have suggested different answers to these questions. "You're allowed to invent any energy curve you want," says Steinhardt.

> "Once inflation starts, it is impossible to turn off completely, leading to an infinite number of universes"

Previous, lower-resolution maps of the CMB weren't detailed enough to give a clear picture of how the process might have played out. If you imagine the speed of inflation changing in the same way as a ball rolling down a hill, it wasn't clear whether the hill was like the inside of a bowl – amounting to inflation that is fast to begin with and slows down at the end – or the outside of an upturned one. Also unclear was whether it was a shallow soup bowl or a tall vase.

Planck's improved view of the distribution of CMB temperatures points to a slide down the outside of a shallow bowl. That makes things difficult, says Ijjas, because such "plateau models" are complicated. They need to be finely tuned to provide sufficient inflation and to avoid a scenario in which the universe collapses into a black hole. Some plateau models therefore call for the universe to have started out a billion times smoother than do simpler models with a steeper energy curve. "That's a very big problem, because inflation was introduced to explain the smoothness of the universe," says Ijjas. Loeb agrees: "If you require the universe to be homogeneous to start with, you're not solving that problem."

This adds up to what Ijjas, Loeb and Steinhardt call an "initial conditions problem" for plateau models of inflation. They also suffer from being unlikely, the trio say, in the sense that models that produce more inflation and produce it more easily are more likely to have occurred. Plateau models fail on that account too. "The models which are now favoured by the data are theoretically exponentially less likely," Ijjas says.

Martin Bucher of the University of Paris Diderot, who was one of the leaders of the Planck team that focused on inflation, agrees that "not every potential is plausible". But he says the measurements do not rule out all of the models with steeper curves. That's because inflation is thought to have pushed most of the universe so far away from us that light from those distant regions has not had time to reach us in the 14 billion years or so since the big bang. The hot and cold spots produced in the very early phases of inflation would be larger than our observable universe, giving us a view of only part of it. "There's tons and tons of inflation that you don't see," says Bucher.

An infinity of universes

The energy curve derived from our observable universe seems to look like an upturned shallow soup bowl. But it could have a steep part too, starting off steeply and then flattening off before falling again – looking for all the world like a Hershey's Kiss chocolate.

Andrei Linde of Stanford University discussed a model with such an energy curve at a physics conference in Santa Barbara, California, in April. Because the potential energy starts out high, there is no need to assume the newborn universe was the same on very large scales. "You have no problems with initial conditions," he pointed out.

According to Linde, who is one of the architects of inflation theory, creating the "shoulder" between the steep and flat part of the curve means tuning the potential by about 1 per cent to fit the Planck measurements. Yet Ijjas and her colleagues say such tweaks are undesirable. "You can always go back and find a potential that will give you what you need, but if you're just reverse-engineering the initial conditions, that's not a good approach to doing basic science," says Loeb. "It doesn't lead you to believe that the model is predictive."

Their third criticism of inflation concerns what Planck doesn't see. Once inflation starts, it is thought to be impossible to turn off completely, leading to an infinite number of universes. But the Planck data shows no obvious sign of them. A giant cold spot has been seen, and some researchers claim it might be a sign of an interaction with another universe. However, its presence may be nothing more than a statistical fluke. Since inflation is supposed to make universes

reproduce like rabbits, Steinhardt argues, why would there be only one cold spot?

A final problem highlighted by Ijjas and her colleagues relates to last year's discovery of the Higgs boson. Most of the energy in the newborn universe is considered to have come from the quantum field associated with the inflaton. The field associated with the Higgs had been thought to have little effect. But that picture might have to change, says Steinhardt, in light of the particle's mass.

Curiously, its value of 126 gigaelectronvolts suggests that the vacuum state of today's universe, known as the Higgs vacuum because it is affected by the Higgs field, is not in its lowest possible energy state. Instead, it appears to be metastable, meaning that at some point it could decay into its lowest energy state. If that happens, it would cause the universe to collapse into a point of infinite density.

Cosmic phoenix

The diagnosis of metastability for the Higgs vacuum is itself on shaky ground, but if it is metastable that presents two problems for inflation. Add the Higgs and inflaton fields, for example, and you wouldn't necessarily have the energy needed to inflate in the first place, says Steinhardt. And if inflation did take place and was extremely energetic, it could have caused the Higgs vacuum to decay and so wiped out the universe.

So what to do? Although Steinhardt was one of the founders of inflationary theory, he has an alternative idea that avoids these problems. He and Neil Turok of the Perimeter Institute for Theoretical Physics in Waterloo, Ontario, Canada, have worked on a theory in which the universe alternates between periods of expansion and contraction. In this cyclic model, the big bang is not a birth but a rebirth, a cosmic phoenix rising from the ashes.

> "A reincarnated cosmos does the same things over the course of its past life that inflation does in under a second"

The reincarnated universe accomplishes the same things over the course of its past life that inflation does in a fraction of a second. Its long, slow contraction, for example, brings together far-flung regions of space explaining why they appear eerily clone-like today. "There's so much more time for physical processes to occur," says Steinhardt.

In the latest version of the theory, developed with Itzhak Bars at the University of Southern California in Los Angeles, the contraction happens so slowly and gently that the Higgs vacuum can remain in its metastable state from one cycle to the next.

Other theorists point out that the cyclic model has a number of shortcomings, which Steinhardt and his colleagues are working to address. "I am not wedded to inflation; in fact, I think we are in need of a grander idea," says Michael Turner of the University of Chicago. "I am not convinced the cyclic model is that grander idea."

Certainly for some physicists, inflation is at an impasse. The bad news is that further experimental tests may not be definitive. Inflation should have shaken space-time itself, triggering gravitational waves that spread throughout the universe. But just how violent this shaking was, and therefore how likely we are to be able to detect the waves today, varies according to each model. Planck and other missions are looking for the subtle imprint these waves left on the CMB and results are expected within a year.

Such waves are not compatible with the cyclic model, since the contraction should have been too gentle to rattle space-time significantly. "If they detect gravitational waves, the cyclic model is ruled out," says Ijjas.

But even if no signal is found, inflation still has a fighting chance. It might just mean that inflation was less energetic than generally thought, says Sabino Matarrese, a Planck team leader at the University of Padua in Italy.

The fact that inflation contains a multitude of predictions works against it, because that makes it difficult to falsify. "If you find something that has in it the potential to explain everything, then that is problematic," says Benjamin Wandelt at Sorbonne University in Paris and a Planck team leader. "Unsinkable theories are highly suspect in science."

The problem, he and others say, is that there is no well-agreed guiding principle from particle physics illuminating what the inflaton should be. "The truth is, we don't have a compelling model for inflation or even a class of compelling models," says Turner.

Matarrese thinks some progress could be made if physicists pin down why the universe is made up of more matter than antimatter, since the energy in the inflaton field should have been converted into particles of both when inflation ended. If gravitational waves are not seen at the expected energy scale after a careful search, "inflation would be in trouble", says Matarrese.

The uncertainty over inflation is "just the tension that we live with at the moment", says Wandelt. Passions can run high in the debate over its existence because missions like Planck are providing a window into the universe's first moments and researchers are anxious to get a better view. "It is a very, very special time in the history of human ideas," he says. ■

Maggie McKee is a science writer based in Boston

Climbing plants are taking over the world's forests. What's going on, asks biologist **William Laurance**

Planet of the vines

GAZE out over a tropical rainforest and the scene looks idyllic – a kaleidoscope of trees festooned with colourful vines, orchids, ferns and lichens. Don't be fooled. Myriad ecological battles are being fought beneath this tranquil surface. None is more embittered than that between trees and their ancient enemies, the vines.

Biologists like myself who study these jungle ecosystems are now seeing a shift in this war. Until a decade or so ago the two adversaries were evenly matched, but vines now seem to be on the march. If that continues, the face of our forests – and of our planet – could be changed irrevocably. We are left scrabbling to unearth the root cause.

If the forest were a financial system, trees would be its old money. Deeply rooted, they grow slowly, investing heavily over time in woody trunks and branches to support their leaves, and providing homes for a zoo of other species. Vines, on the other hand, would be the flashy junk-bond traders. Representing up to half of the plant species in a typical rainforest and producing up to 40 per cent of all leaves, they are down-and-dirty competitors. They invest almost nothing in supportive tissue, instead taking advantage of the trees' investments to scramble up to the top of the forest and produce great flushes of leaves that bask brazenly in the full sun.

Francis Putz, a biologist at the University of Florida in Gainesville, highlighted this fraught relationship in a 1980 paper entitled "Lianas vs trees". Lianas, or woody vines, can grow to be hundreds of metres long, with stems over half a metre across. Trees pay a high price for their presence. Lianas can strangle and deform a tree's branches, their dense foliage robs trees of life-giving sunlight, and their roots scarf up vital nutrients and water. Trees bearing lianas usually grow more slowly, reproduce less and die sooner than those without. Once lianas reach the canopy, they often climb laterally, effectively roping trees together so that, when one falls, it can drag down others. This is why loggers hate them: if they don't cut every liana linked to a tree before felling it, another may be yanked down on top of them. "Loggers call them 'widow-makers'," says Putz.

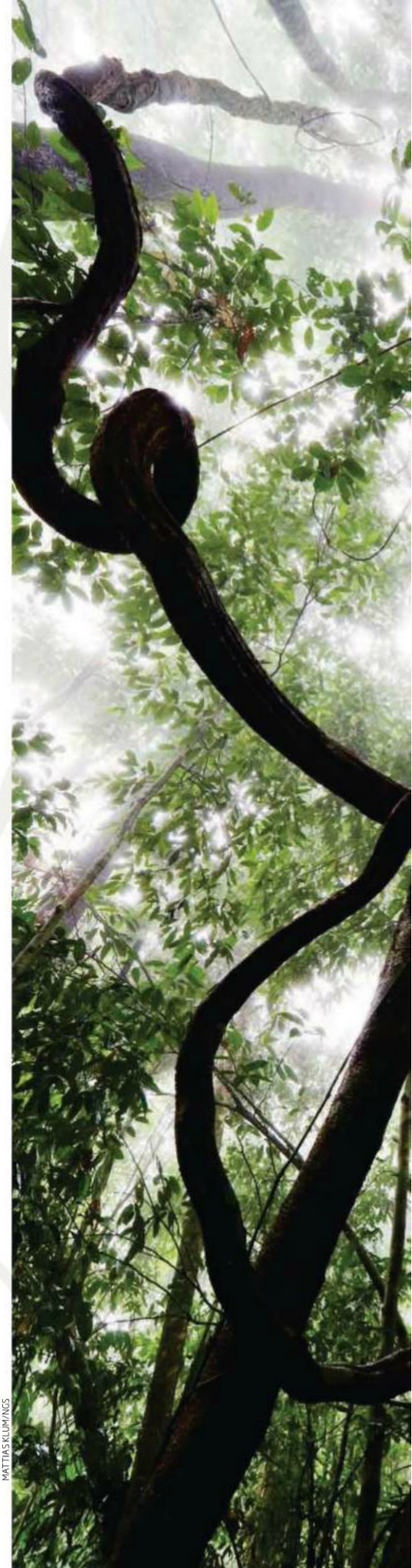
There are obvious reasons why some vines are becoming more prevalent. Humans have introduced invasive species, such as the rubber vine to northern Australia and kudzu to the south-eastern US, that smother native forests, grasslands and waterways. Most vines are light-loving, and increase rapidly in forests that have been fragmented by agriculture or selectively logged. Small, regenerating trees on the edge of disturbed forests provide ideal trellises for climbing quickly into the canopy. A decade ago, my colleagues and I revealed much higher liana abundances in fragmented than in intact Amazonian forests. Trees in these areas are beleaguered, dying two to three times as fast as normal.

Dynamic drivers

But vines are also proliferating in undisturbed forests. Oliver Phillips of the University of Leeds in the UK and his colleagues revealed in 2002 that lianas had increased sharply at the expense of trees at sites across western Amazonia. Something similar has been seen in nearly a dozen other intact forests in Central and South America. "It was controversial at first," says Phillips, "but few doubt it now."

What's happening? A likely cause is that tropical forests around the globe are becoming more dynamic, with trees dying and regenerating more rapidly – conditions that strongly favour vines. It is possible that global warming is intensifying windstorms that increase tree fall in the affected areas, yet there is little evidence for such an effect.

Instead, a more subtle driver seems to be at play: rapidly rising levels of atmospheric carbon dioxide. CO_2 fuels photosynthesis, and the more there is, the faster plants grow. Faster



MATTIAS KLUM/NGS

Vines stop at nothing in their scramble towards the light

growth creates more competition among plants for light, space and nutrients, which in turn drives higher rates of tree death and regeneration. Rising CO_2 could also favour vines directly. Several studies over the past few years suggest that vines, with high photosynthetic rates, an abundance of energy-producing leaves and little costly supportive tissue, are primed to take advantage of rising CO_2.

This isn't to imply we know everything about the onslaught of vines. So far the trend has been spotted in undisturbed forests only in the Americas. Long-term studies are needed elsewhere to ensure this isn't a coincidence of geography. I wonder, too, about the fate of remote forests I have studied in the Congo basin. Vines there are naturally abundant because of disturbance by forest elephants. Yet elephant populations are collapsing from overhunting. Might vine numbers in these forests actually begin to decline?

Most evidence, however, suggests Earth is heading for a viney future. This worries ecologists like Stefan Schnitzer at the University of Wisconsin-Milwaukee. "Vines can change forests in a lot of ways," he says. "They hit big, slow-growing trees far harder than smaller, faster-growing species, meaning they can probably change the entire composition of the forest."

It's not just trees that are at risk. Ainhoa Magrach, a postdoctoral colleague of mine at

"Vines are down-and-dirty competitors, producing great flushes of leaves that bask brazenly in the sun"

James Cook University in Cairns, Australia, has found that plants that live on trees, such as ferns, tend to be excluded in regions where vines are dense. These ferns are little islands of biodiversity, sustaining many animals in the rainforest canopy. A few species have mutualisms with aggressive ants that attack encroaching vines, but most are not so lucky.

The biggest worry is that proliferating vines could reduce carbon storage. Forests lock up billions of tonnes of carbon in woody tissue, and when vines kill or suppress trees some of that carbon is released into the atmosphere. Studies in Panama and Amazonia suggest rampaging vines replace just a small fraction of the carbon they cause trees to release. That could induce a positive feedback, with still more greenhouse gases and a warmer future for us all. If that goes too far, we really could be heading for a planet of the vines. ■

William Laurance is a distinguished research professor and Australian Laureate at James Cook University in Cairns, Australia, and holds the Prince Bernhard Chair in International Nature Conservation at Utrecht University in the Netherlands

Can technology solve the mystery of the Lyubov Orlova? Richard Fisher goes in search of a ghost ship

Missing!

OUT in the endless grey of the Atlantic Ocean, a vessel drifts alone. The only sound in the dining room is the wind. The only smell in the galley is rust. The cabins that once held 100 passengers lie empty; there's not a soul aboard. Along the bow, a row of drip-stained letters spells its name: Lyubov Orlova.

The Orlova is a modern-day ghost ship. It disappeared on 4 February 2013, en route to the Dominican Republic, without power or crew. The loss triggered a global hunt involving coastguards hoping to find the ship before it ran ashore or struck an oil rig; the coordinators of a new satellite system with a point to prove; and even a team of would-be treasure seekers. Each had their own prize in mind: prevention of disaster, reputation and glory, or a salvage bounty worth a million dollars. How hard could it be?

In fact, it proved far from easy. This raises some important questions: in an age of global surveillance, when planes and satellites can watch our every move, how can we lose a 1400-tonne ocean liner? And what else might be roaming the high seas, abandoned and long forgotten?

Named after a Soviet actress, the Lyubov Orlova was bolted together in Yugoslavia in 1976. In its heyday, it went on expeditions to the poles: while the vessel's strengthened bow brushed aside broken ice, tourists snapped gleaming icebergs from the observation deck or sipped drinks in the lounge.

By January this year, however, the Orlova had fallen into a sorry state, derelict and impounded in the frozen harbour of St John's in Newfoundland, Canada. The crew had dispersed, the power was gone and the only life onboard was vermin.

The government body responsible for the harbour – Transport Canada – wanted the vessel gone. They finally got their wish when the Orlova was sold and its new owner hired a tug to tow the vessel to the Dominican Republic, where scrap merchants would dismember it piece by piece. The Orlova's time was up – or so it seemed.

After leaving port on 24 January, bad weather set in and the tow line parted. The Orlova began to drift dangerously close to oil fields, which prompted oil company Husky Energy to send a ship to intercept it and regain the tow. Successful, they handed the line back to a Transport Canada vessel. The Orlova's fate at the breaker's yard appeared sealed. Then the tow was lost again.

Or perhaps it was released deliberately – Transport Canada won't comment. Whatever the truth, by early February, the Orlova was on its own in international waters (see map, page 46). Drifting, abandoned, it disappeared.

Around a week later, on the opposite side of the Atlantic, one man was about to discover he had a problem. On 11 February, Chris Reynolds, the director of the Irish Coastguard, was on the phone to a coastguard contact in Canada, trying to set up an interview with Canadian astronaut Chris Hadfield for Ireland's national broadcaster. Towards the end of their conversation, the Canadian officer delivered a bombshell: "Oh, by the way, we've lost a ship."

Reynolds knew what this meant: driven east on prevailing Atlantic currents, the vessel would bear down on Ireland. It could run aground, triggering a major clean up, or drift into shipping lanes or oil fields and put lives in danger. He needed to find that ship.

Reynolds had spent his life at sea but had never faced anything on this scale before. While plenty of abandoned boats, containers and debris are thought to float on the ocean, few rival the Orlova's 100-metre-long hull. One of the largest in recent years was the Ryou-Un Maru, a 50-metre trawler that appeared off the US coast last year, swept from Japan by the 2011 tsunami. Within days, Reynolds and his team became coordinators of an ocean-wide search.

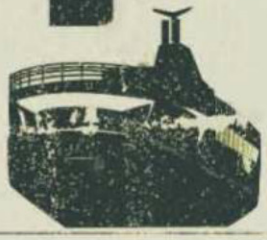
Speck on the sea

The Irish team soon realised the scale of their task. It's usually easy to find ships – all large vessels are required by law to broadcast their position with a transponder called the Automatic Identification System. But the Orlova's AIS was dead. Sightings were unlikely too – the ocean is too vast. Nor would satellite-mounted cameras help: though trained on the ocean, their resolution isn't high enough to make out a ship without zooming in, and for that you need to know where to look. Besides, the north Atlantic is often cloudy. So Reynolds turned to specialised search and rescue software that he hoped would predict the Orlova's location based on known currents and prevailing winds.

However, predicting the ship's trajectory proved challenging. The software was programmed to find small objects such as ›

I.LOVEDUST

LAST SEEN

DRIFTING  4TH FEB

ABOUT **600** KM

NORTH-EAST OF ST JOHNS

NOW IN THE MIDDLE OF THE OPEN OCEAN

NOBODY

[redacted] WAS

ON BOARD . . . .

jet skis or yachts, not a large vessel sitting high in the water that strong winds could blow around unpredictably. And with more than a week elapsed since the Orlova went missing, their search area was enormous.

Reynolds and his team weren't the only ones looking. News of the Orlova had reached Pim de Rhoodes, captain of the Fourcault, based in Antwerp, Belgium. He and his adventure-hungry crew usually earned a living running shipwreck diving trips. But de Rhoodes realised that putting a line onto the Orlova in international waters could bring a windfall.

If they recovered it, they would either get a substantial return fee, or they could claim ownership and then sell to scrap merchants for up to €700,000. There was even talk of hawking the vessel's furniture and fittings. Ghost-ship memorabilia promised to fetch a good price online: the ship had already inspired a fake twitter feed, smartphone app and a blog selling T-shirts. On 16 February, he and a volunteer crew set off into the Atlantic, hoping for a stroke of fortune.

For Reynolds, luck seemed in short supply – until a timely phone conversation. He was talking to Guy Thomas, a maritime surveillance consultant based in Baltimore, Maryland, who had asked him to speak at a conference. Reynolds explained that he would have to pull out. "We have a ship inbound on us," he said. Thomas became excited. He had an idea; a project he had been working on for years. "If it's still afloat," he said, "I think we can find it for you."

Invisible pirates

As a former US navy reconnaissance engineer, Thomas had watched the ocean for much of his career. However, he had grown frustrated by the fact that pirates, illegal trawlers and the like can remain almost invisible. He realised there was one type of sensor that could keep tabs on these vessels – it just wasn't looking.

Satellite-based synthetic aperture radar (SAR) systems are used to measure surface features like topography. To do this, they transmit a radio pulse over a broad area, then calculate the shape of the Earth's surface based on the timing and type of signal scattered back. Unlike cameras, they can comb wide swathes of ocean with a resolution high enough to spot a ship – and the signal penetrates cloud. Thomas has already established a project called C-Sigma that brings SAR satellite operators and maritime authorities together. Now he needed to persuade them that it worked and finding the Orlova would be the perfect demonstration.

Thomas asked an SAR satellite operator from Italy, called E-Geos, to donate time on their four satellites that zip pole-to-pole. The Irish team supplied their best-guess coordinates for the liner, and the satellites went to work.

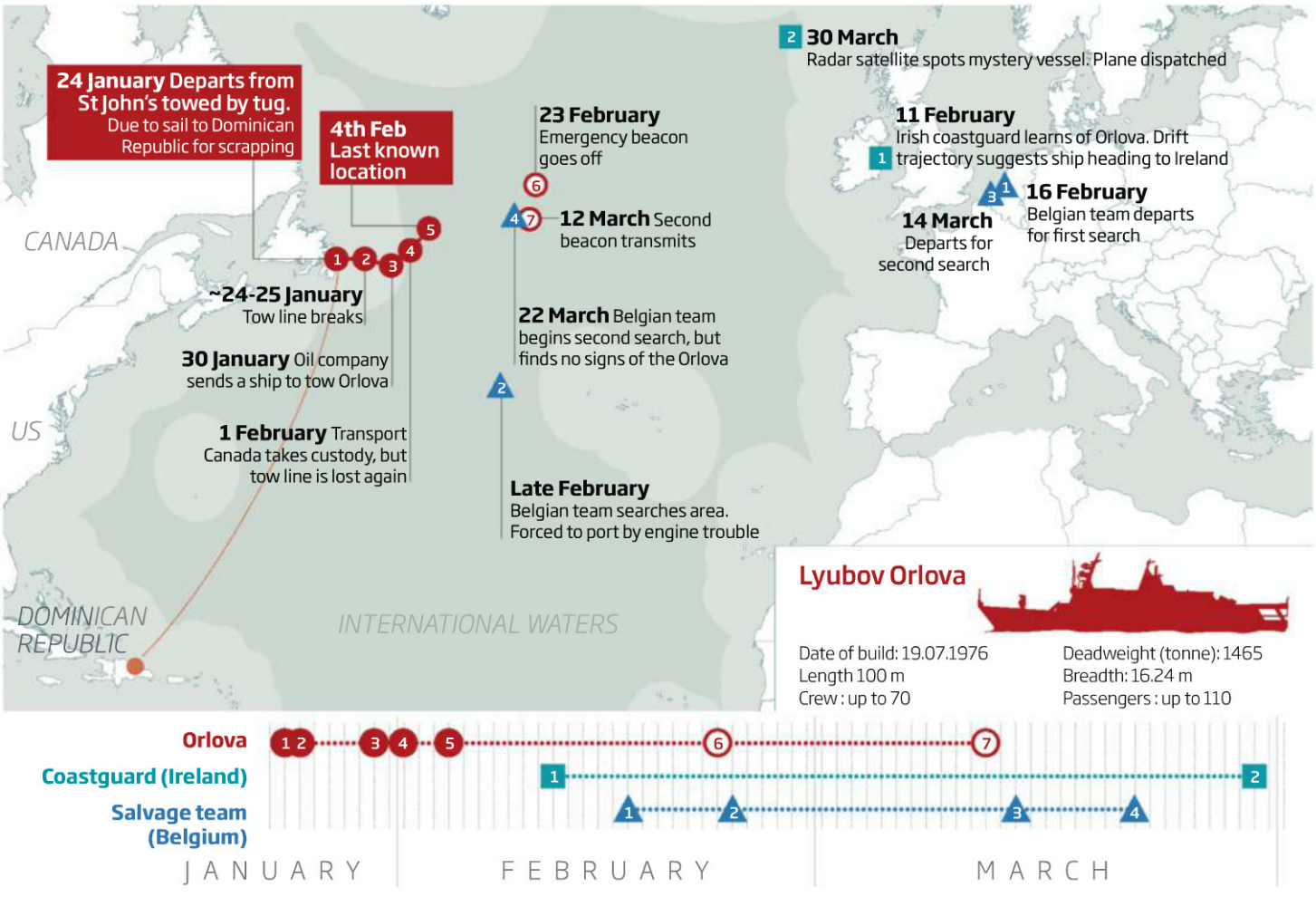
As the first images came in, the Irish team ticked off radar blips from vessels with active AIS beacons, hoping to find a silent blip remaining. A few times they thought they had it... but then on the next satellite pass the blip would disappear. The Orlova wasn't there.

Out on the ocean, de Rhoodes and his crew were struggling too. In the Atlantic winter, the waves were as daunting as mountains. Then, just a day from their search zone, one of their two engines failed. Reluctantly they limped back to Antwerp, resolving to sail again.

Meanwhile, rumours circulated. An article by Agence France Presse claimed a US maritime agency had seen the ship on

Missing: a 100-metre ship

With radar-equipped satellites and long-range aircraft to call on, finding a lost ship should be a simple task, yet the Lyubov Orlova has disappeared



21 February; there was also talk of a sighting in a Caribbean port. None was confirmed.

Then came a twist. On 23 February, the Irish coastguard suddenly picked up a distress signal from one of the Orlova's Emergency Position-Indicating Radio Beacons. These devices activate when a ship goes down, or when one of its lifeboats hits the water. Clearly this beacon's battery had some power left and it gave them an exact position – towards the north-east edge of their search zone.

Almost everyone assumed that this was the Orlova's last gasp: it must have sunk. The danger of collision or grounding was over and the satellites were called off.

Then, almost two weeks later, there was a surprise: another distress signal from a second beacon. This was mystifying. If the Orlova had sunk, how could this be? Perhaps it was shedding lifeboats. Or maybe the ship had capsized and was partially submerged. Whatever the cause, the signal couldn't be ignored. The Irish search was back on.

But would the Belgians beat them to it? De Rhoodes was already closing in on this new location, thanks to an unlikely tip-off. One day, an Irish man in uniform turned up, claiming to know the Orlova's position. When de Rhoodes checked with other sources, the coordinates seemed plausible, so they set out. Their destination turned out to be close to the second signal's location.

By 22 March, de Rhoodes team had arrived and their helicopter was making sweeps of the area. The swell made take-off and landing dangerous, but it was worth the risk: they could scan 50-kilometre-wide strips of sea at a time. They saw a tanker and, in the distance, a passenger ship. "That's it!" thought de Rhoodes. It wasn't. The vessel's captain answered their radio calls.

They saw five ships in all, none of them ghosts. Days later, as a last-ditch effort, de Rhoodes turned off his engines and let his ship drift to see where the currents might have taken the Orlova. Surprisingly, the winds accelerated them west. We aren't going to find this ship, he thought. Then the weather worsened, so he headed for home.

Two blips good

By now, the Irish were ramping up their search effort. Reynolds asked the satellites to make another pass – and at last, success! They got two blips: one possibly a lifeboat, the other large enough to be a liner, moving dark and quiet up between Iceland and Scotland. It was time to launch the planes.

In early April, two planes took off, one to hunt each blip. The plan was to display live images to an audience at a maritime surveillance conference in Dublin Castle. But the plane dispatched to the position of the smaller blip found nothing. If there had been a lifeboat, it had sunk. That left the second pilot, scouting the sea north-east of Ireland. Finally, it located a ship. Could it be the Orlova at last?

UNIVERSAL IMAGES GROUP / GETTY

"Then, almost two weeks later, there was a surprise: another distress signal from a second beacon"

Looking back, Reynolds lets out an exasperated laugh. "It was a Spanish fishing vessel with all its transponders turned off," he says, fishing where it shouldn't be.

The Orlova had disappeared. Six months on, the ship still hasn't turned up.

Disappointing? Certainly. Wild-goose chase? Reynolds thinks not. The events have highlighted that even in the 21st century, our knowledge of what occurs on the ocean is surprisingly poor. If it is so hard to find the Orlova, how can we hope to keep tabs on pirates or illegal fishing vessels?

It's the wild west out there, says Reynolds. We are very good at recognising typical behaviour, vessels behaving themselves, he says. "But our systems don't allow us to see people who don't want to be seen." We need better policing, he argues, if we are going to exploit wind and tide energy at sea, prevent illegal fishing, mine resources safely and ensure safe passage. "Everybody talks about using maritime surveillance to find the bad guys," says Reynolds. "For me it's about allowing the good guys to do good things."

Radar satellite technology isn't perfect, but as the hunt for the Orlova shows, it can easily spot small vessels – if used in the right way. "We could build a maritime surveillance system today," says Thomas.

So is the Orlova on the seabed? There are tantalising reasons to believe otherwise. For starters, the ship had been made extra-buoyant for its final voyage, meaning it would have been able to stay afloat in heavy weather. It also had six lifeboats, each with a distress beacon. If they had all hit the water, why were only two signals picked up? "I think it could float for years," says de Rhoodes. "If I have a location, I'll go for it, no problem."

It is certainly not unprecedented for a ship or other large object to be lost for long periods. In 2012, a 20-metre-long Japanese floating dock washed up in Oregon – one of three lost in the tsunami 15 months earlier. Since 2000, at least seven ghost ships have been found wandering the seas, from a rusted, 80-metre-long tanker off Australia with no known owner to an empty yacht found near Sardinia with half-eaten meals on-board. And an estimated 2000 shipping containers go overboard each year – around a third of which float.

However the record probably belongs to a Swedish steamer called the Baychimo. Abandoned in pack ice in 1931, it was seen drifting at various points along the Alaskan coast for more than 30 years. It was last sighted in 1969; a search by the Alaskan government in 2006 turned up nothing. Perhaps the Orlova faces a similar fate? Somewhere out on the grey, the liner may still drift, silent but for the slap of waves on metal, and forever lost. ■

Richard Fisher is a feature editor at *New Scientist*

Pursuing happiness for all it's worth

Is happiness in our minds – or in our wallets? Is unhappiness our fault or yet another thing to blame on government? **Debora MacKenzie** finds out

GEORGE STEINMETZ/CORBIS

Hardwiring Happiness: The new brain science of contentment, calm, and confidence by Rick Hanson, Random House, $26

Scarcity: Why having too little means so much by Sendhil Mullainathan and Eldar Shafir, Allen Lane, £20

The Great Escape: Health, wealth, and the origins of inequality by Angus Deaton, Princeton University Press, $29.95/£19.95

HAPPINESS is a minefield. Many believe it is what we are here for, that a life is well-lived if it makes you happy. That view, like modern science, comes from 18th-century humanism: the US Declaration of Independence made the pursuit of happiness a right as inalienable as liberty and life itself, and one worth going to war for. Of course, the Declaration continued, that's why we have governments – to protect that pursuit. So is it up to "them" to make "us" happy? Or are we all responsible?

Folk wisdom says that whatever causes happiness, it ain't money. The data, however, disagree. Angus Deaton, an economist at Princeton University, has written a book not primarily about happiness, but about the "great escape" from poverty and poor health that much – but not all – of humanity made in the past century. This is one of the most momentous events in history, and deserves attention. But has it made us happy?

Up to a point, says Deaton: about $1800 in GDP per person, Kenya's level. The further your country is below that, the less likely you are to say you felt happy yesterday. Above that point, as countries get wealthier, their people are somewhat more likely to report being happy, but the two do not correlate closely – and income makes no difference to stress, worry or anger. Similarly, within the US, more income means more happiness, at least up to $70,000 a year. Above that, more appears to make no difference.

The problem for many in the US is getting past that number. Deaton details how increased wealth in the US accrues almost entirely to the rich, generating spiralling inequality. That may be a source of unhappiness by itself, and disappointingly, Deaton doesn't explore this. It does mean

that while wealth has grown steadily in the US since the mid-1970s, the typical American family's hasn't. So perhaps it is no surprise, he notes, that they also report no increase in happiness.

Deaton's main argument is that change is never distributed equally, so economic growth always results in inequality. The crucial question is, what next? Inequality can spread prosperity if those left behind can catch up. But with too much inequality, Deaton argues, the rich protect their interests by pulling the ladder up behind them – think of increasingly unaffordable healthcare and universities. Too much of that, he says, and improvement stops for everyone.

I would have liked more about the idea that limits to inequality may be in everyone's interests. Instead, Deaton vents about development, claiming most efforts to limit population are irrelevant and coercive. Certainly, many population experts don't agree with him. He insists that aid to poor countries merely breeds corruption and stifles home-grown development.

That seems a bit too Reaganomic to be the whole answer, although we would help many poor nations more by buying their exports than by giving them handouts. And one cannot disagree when Deaton says that, if we want to help, we should buy research to help them cure diseases and grow food.

If the poor are to make their own way out of poverty, however, they will need to be able to think clearly. That could be difficult. A very different flavour of economist, Sendhil Mullainathan at Harvard University, and a psychologist, Eldar Shafir at Princeton, have studied how scarcity itself affects the brain.

No one who has dieted will be surprised to learn that the brain focuses ferociously on what it feels is lacking. This reflex evolved to help us find what we need. The team's real insight is that it applies to all scarcities, not just of money, but of time and even social contact. We "tunnel" in on the scarcity and ignore anything outside.

Within that fierce focus, the future looks less menacing than the scarcity we face now. So we borrow money, then borrow more, disregarding future costs as interest mounts, until we are deeply in debt. Time debts spiral in the same way. Focusing on scarcity hogs our mental "bandwidth", leaving less brain power for other things. We forget tasks, resolve and judgement slip.

This is supported by fascinating psychological experiments, where contrived scarcities of time or resources make experimentees behave as the model predicts: they tunnel in, make bad decisions, run up debts. The authors look mainly at how this "scarcity trap" affects poverty (*New Scientist*, 7 September, p 17). But it affects happiness, too: as Deaton reports, being poor does not make you happy, and nor do other scarcities.

Observations of real poor people, meanwhile, suggest that constant scarcity means a constant shortage of bandwidth, explaining why poor people can seem self-defeating: they forget pills, miss deadlines, don't fill out forms. Efforts to escape poverty are derailed by inevitable, small setbacks for which there are no spare resources, material or mental. The rich have dismissed this with social Darwinism ("they're poor because they act like that") or Victorian moralising ("they're just lazy"). Instead, the research suggests it's the way all our brains handle scarcity.

"Within the US, more income means more happiness, at least up to $70,000 a year"

This seems a much better, psychologically informed way to approach poverty. It can be a bit glib sometimes: any problem, it seems, can be ascribed to bandwidth. But it does suggest a few solutions, such as avoiding bandwidth-sapping administrative hurdles in programmes for the poor. Moreover, we might all be better off – even happier – if we recognised our own obsessions with scarcity.

For real self-help, though, give me a meditating Californian neuropsychologist. Rick Hanson also believes the brain has evolved to focus on negative events, three kinds in fact, which when you look at them also boil down to scarcities: of security, of resources, of social connection.

This focus had evolutionary advantages, but in a complex modern world the obsession is unhelpful. It seems Hanson has observed, through his clinical practice, the same scarcity-obsessed brain as Mullainathan and Shafir. Arguably, their experimental evidence might support his broader model for how it messes up our lives.

Broader, because Hanson concentrates on applying the model. He observes that tunnelling in on unhappy means we pay undue attention to happy. That suggests a way out: Hanson proposes that if we take a few minutes several times a day to focus in a meditative way on even trivial occasions when these scarcities are remedied, instead of racing back to the brain's dark obsession, we will be happier.

He offers no direct proof it works, though he does cite studies supporting the psychology, and showing that repeated mental activities do change the brain. The book is mostly about such techniques, and if you can handle the language of meditation, who knows – it might change your life.

Meanwhile, I'm sure some leaders would like to use this kind of thinking to blame citizens for their unhappiness. Tell that to a family struggling to hold down multiple jobs, stuck way under that magical $70,000. It may be our job to pursue happiness, and the insights of psychology can help us discover how our brains betray us, and rein them in. But as the Declaration said, governments are instituted to make that pursuit possible. Levelling depressingly uneven playing fields is their patch. ■

Scared: the rich pull up the ladder after them when society gets too unequal

BRUCE GILDEN/MAGNUM PHOTOS

Debora MacKenzie is Brussels correspondent for *New Scientist*

Cities of dreams

New York, Mumbai and Berlin offer up a blueprint for urban living and democracy

Participatory City: 100 Urban Trends at the Guggenheim Museum, New York, 11 October to 5 January 2014

Happy City: Transforming our lives through urban design by Charles Montgomery, Allen Lane/Farrar, Straus and Giroux, £16.99/$27

Reviewed by Kat Austen

THERE is an unspoken assumption that city dwellers are secretly hankering to move to the countryside, or at least to the suburbs. The pollution, the noise, the crime: who would choose to live in a place like that?

The answer is, most of humanity. A year or two ago – nobody is quite sure when – the world's urban population overtook the rural one, and the World Health Organization predicts that by 2050, 70 per cent of us will be urbanites.

People flock to cities for many reasons; in the developing world it is often to swap a life of grinding rural poverty for a life of slightly less-grinding urban poverty. But for many people, cities offer a better, more fulfilling and – ironically – greener life. Urban life sparks innovation through social interactions and urban dwellers have, on average, a smaller environmental footprint. Cities might be safer too – you are more likely to die a violent death in the rural US than in a city.

Still, there is always room for improvement, and with all that innovation going on you would expect urbanites to find solutions to problems such as higher stress levels and crime rates.

That is the thinking behind Participatory City, an exhibition at the Guggenheim in New York. It is the culmination of a two-year project by the museum and BMW which sent a pop-up laboratory to New York, Berlin and Mumbai to take a closer look at city life – and the life of cities – through the eyes of their inhabitants.

Via a series of workshops, events and experiments, the lab encouraged scientists, architects, designers, artists and the public to confront the issues faced by city dwellers. The end product is a compendium of 300 trends that the organisers consider to be the most important issues in urban living. The exhibition will showcase a selection of 100 in a series of multimedia pieces.

One prevailing theme is harnessing city dwellers' imaginations and experiences to find ways to improve city living. The projects are interesting and often collaborative, from guerrilla gardening through participatory park design to an open discussion about rainwater harvesting, which resulted in the design of a public bench that collects water.

"The World Health Organization predicts that by 2050, 70 per cent of us will be urbanites"

The exhibition also highlights the use of digital tools to crowdsource the collection of data, such as the use of apps to map transit in Mumbai, or the food supply chain in Berlin.

Similar ideas are espoused in *Happy City* by writer and photojournalist Charles Montgomery, who was involved in the project. Montgomery argues that while city planners and politicians make a difference, "we are all... natural stewards and owners of the city". He goes on to give heart-warming – though not always wholly convincing – examples of individuals reclaiming the streets, such as the 12-year-old in Saratoga Springs, New York, whose campaign overcame his school district's edict that prevented him from cycling to school, or the Portland community who painted a piazza on the tarmac of a busy intersection.

Amid all the positivity and empowerment it is easy to forget that cities do have serious problems, from urban decay to pollution, crime and stress. Fortunately, these are not entirely ignored by the exhibition.

Psychologist Colin Ellard of the University of Waterloo in Canada assessed how people reacted psychologically and physiologically to different urban environments in the three cities the project visited. Using questionnaires and stress sensors, he found that in certain environments – most notably busy intersections – people were bad at judging how physically aroused they were. This is probably due to habituation, says Ellard – we get used to a high level of stress psychologically but our biological reactions remain the same, possibly to the detriment of our health. Any decisions made by the public under the influence of this kind of habituation could conceivably send urban design off in the wrong direction.

It's a problem that, like many others, can be solved by people being better informed. The exhibition is a reminder to city dwellers like me that we are lucky to live in such vibrant, exciting and innovative places – and that we all have the power to make them even greater. ■

The pop-up urban laboratory took a closer look at city living

ROGER KISBY

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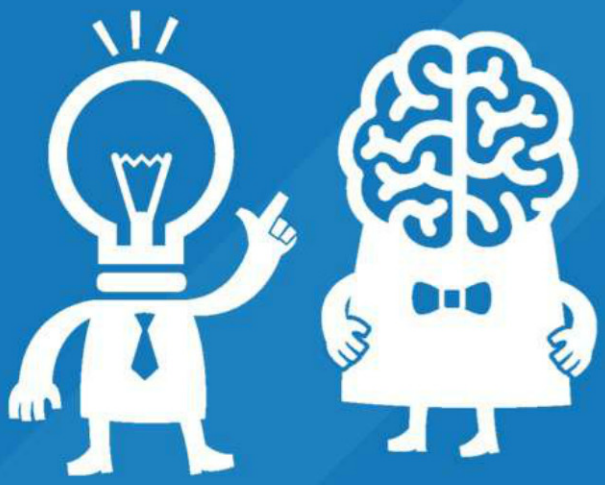

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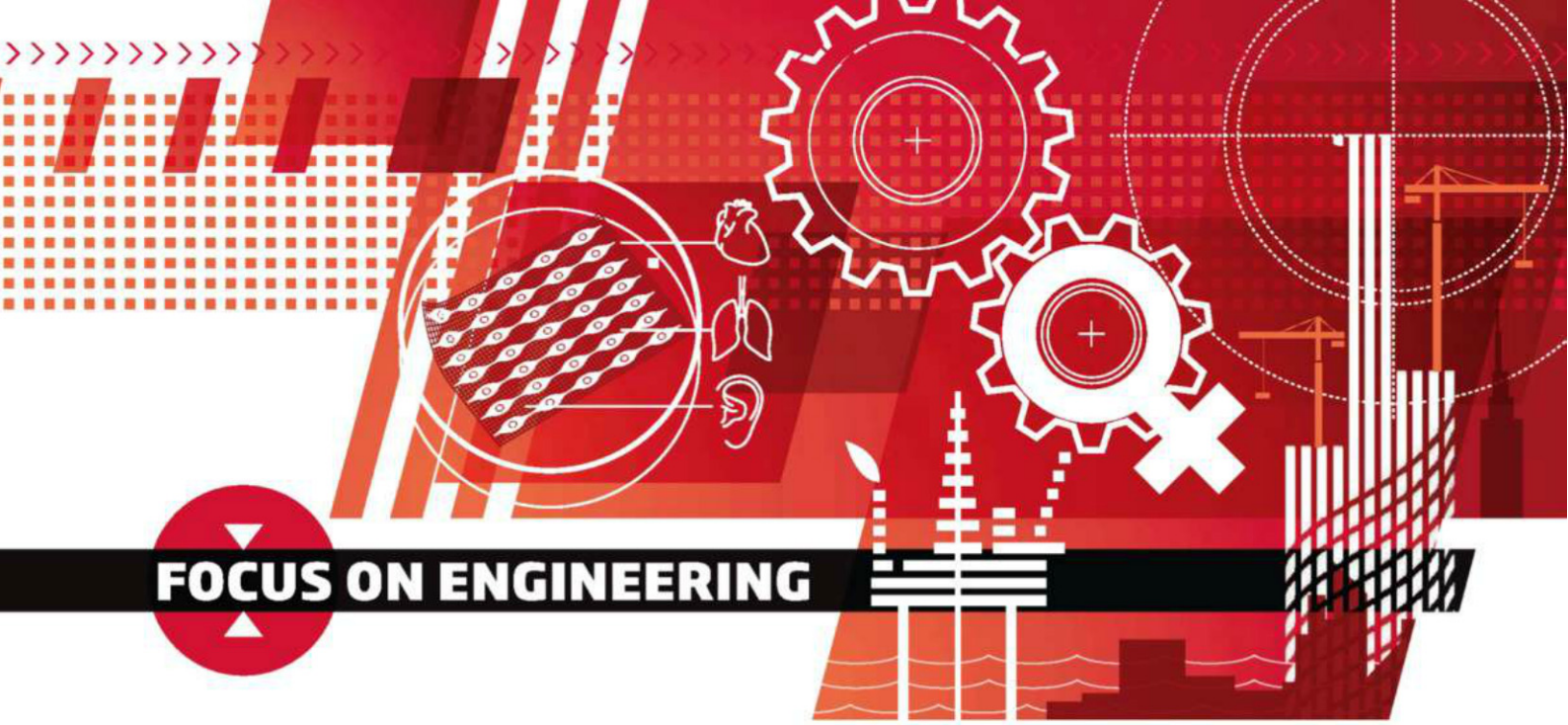

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Application closing date 3rd December 2013

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Please email this, before the closing date, to Susan Allwright at nceodirector@nerc.ac.uk

Further details about this role are available at www.nerc.ac.uk/nceodirector

Closing date for applications: 4.00pm local time, 13th November 2013

Interviews will be held in London on 11th December 2013

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Imperial College London

Department of Epidemiology and Biostatistics
School of Public Health

Lecturer/Senior Lecturer in Molecular Epidemiology (non-clinical)

Salary Range:
£45,040 – £50,190 per annum (Level C, Lecturer)
From £55,340 per annum (Level D, Senior Lecturer)
(Appointment level will depend upon qualifications and experience)

This post is based in the Department of Epidemiology and Biostatistics within the School of Public Health, at the College's St. Mary's campus in Paddington.

Research as well as teaching are considered an integral part of the post. The postholder will play a leading role in the development of research and methodologies to analyse multi-omics data including genomic, epigenomic and metabolomic data. The Department and the Imperial College Biomedical Research Centre (BRC) have world-leading epidemiological resources with intense phenotyping on cardiometabolic traits and rich genomic and metabolomic data. The post-holder is expected to use these resources and to develop novel approaches to analyse multi-dimensional datasets in order to understand aetiological pathways in relation to cardiometabolic and other disease traits.

The post will also involve the usual administrative duties associated with a busy academic and research-active environment. The postholder may also be required to undertake other duties, as required by the Head of Department and Head of School.

The successful candidate must have a PhD or equivalent in Epidemiology, Statistics, Bioinformatics, Computing or another quantitative science; have a strong track record of publications and attracting high levels of research funding and strong experience in working and analysing large-scale epidemiological datasets including excellent knowledge of relevant software.

Experience in working with molecular epidemiology data such as genomics or metabolomics is essential.

This is a full time, open ended post.

Informal enquiries about the post can be directed to Professor Paul Elliott (p.elliott@imperial.ac.uk).

Our preferred method of application is online via our website http://www3.imperial.ac.uk/employment. Please complete and upload an application form as directed. **Please quote reference number: SM195-13**.

Closing date: 27 October 2013.

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Imperial College London

Department of Epidemiology and Biostatistics
School of Public Health

Reader/Professor in Biostatistics and Computational Biology (non-clinical)

Salary Range:
£55,340 per annum – Level D - minimum salary for appointment as Reader
£70,350 per annum – Level E - minimum salary for appointment as Professor
(Appointment level will depend upon qualifications and experience)

Applications are invited for the new post of Reader/ Professor in Biostatistics and Computational Biology in the Department of Epidemiology and Biostatistics within the School of Public Health. The successful applicant will be joining a vibrant and successful research department with a strong tradition of biostatistical and epidemiological research, and excellent epidemiological, cohort and computing resources.

The postholder will be based at the St Mary's campus (Paddington) as part of the MRC-PHE Centre on Environment and Health hosted by the School. We are leading several high-profile international projects on the application of omics technologies to epidemiology.

We are looking for a candidate with vision and drive, with an established international reputation and a well-attested record of high-impact research and expertise in this field of research. The appointee will have a proven track record of grant awards and high-impact publications, with particular emphasis on the analysis of complex, high-dimensional data including omics data.

The appointee must have a higher degree in a relevant research area (MD, MS, PhD or equivalent); experience of training undergraduate and postgraduate students; experience of supervision of higher degrees (PhD, MD(Res)) and junior medical staff.

Evidence of management and administration experience would be desirable.

This is a full time, open ended post.

Informal enquiries about the post can be directed to Professor Paul Elliott (p.elliott@imperial.ac.uk).

Our preferred method of application is online via our website http://www3.imperial.ac.uk/employment. Please complete and upload an application form as directed. **Please quote reference number: SM194-13**.

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Athena SWAN Silver Award

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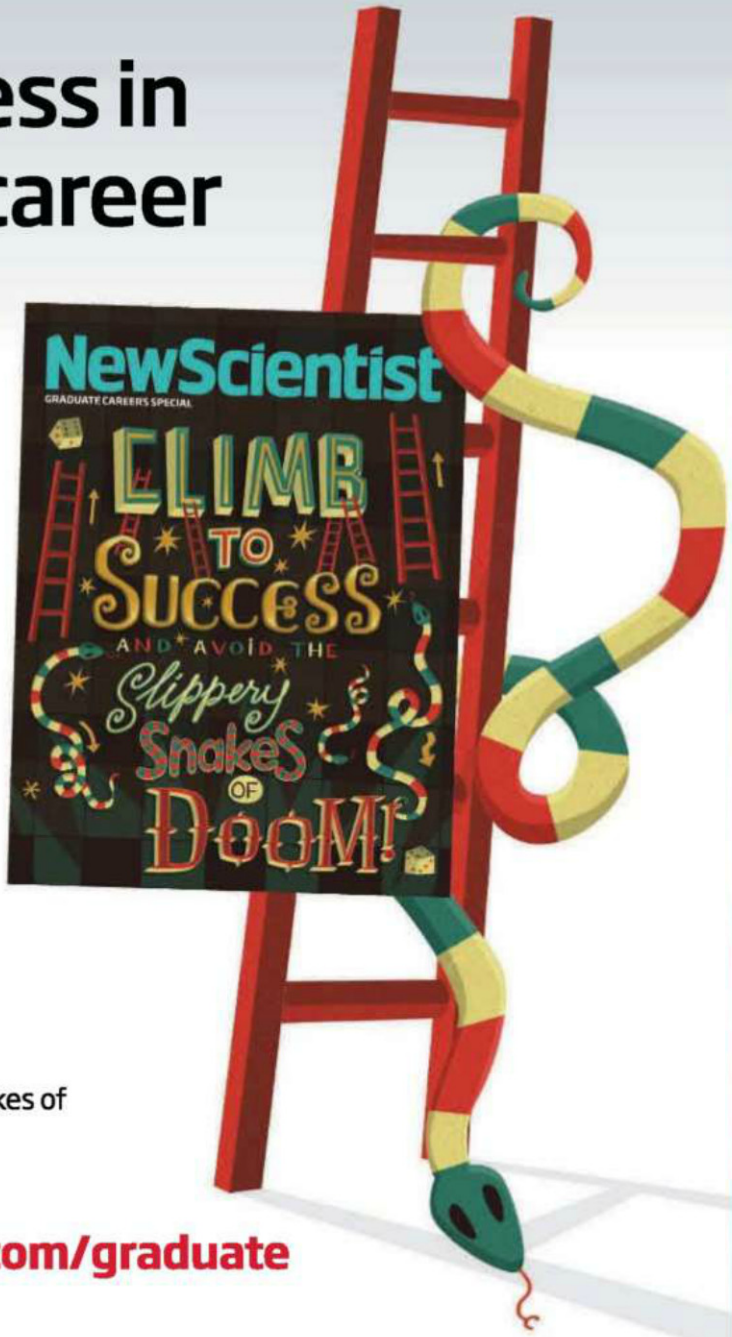

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Call for Applications for September 2014

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- Genetics, Genomics and Systems Medicine Research
- Clinical Trials and Implementation Research
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Website:
http://www.gla.ac.uk/researchinstitutes/icams/postgraduateresearchopportunities/bhf4yearphdprogramme/

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Prof Andrew Baker on 0141 330 1977, email Andrew.H.Baker@glasgow.ac.uk
Mrs Ruth Bennett on 0141 330 2833, email Ruth.Bennett@glasgow.ac.uk
Deadline for applications: 15th November, 2013

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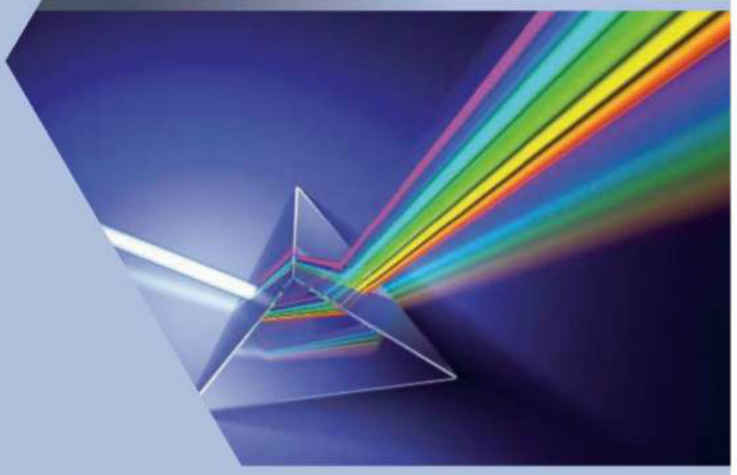

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Cancer Research UK 4 Year PhD Studentships 2014

Cancer Research UK Manchester Institute

Applications are now open for Cancer Research UK 4 year funded PhD studentships at the Cancer Research UK Manchester Institute (previously known as the Paterson Institute for Cancer Research) commencing in Autumn 2014. Four projects are on offer, spanning the whole spectrum of cancer research from the molecular and cellular basis of cancer to translational and clinical research, and the development of therapeutics.

Bioinformatics	Crispin Miller: 'Regulatory non-coding RNA systems in cancer'
Clinical & Experimental Pharmacology	Caroline Dive: 'Identification of novel anticancer therapeutic options for small cell lung cancer'
Molecular Oncology	Richard Marais: 'Investigating signalling and gene regulation in Uveal melanoma'
Systems Oncology	Claus Jorgensen: 'Tumour-stroma signaling and therapeutic resistance'

At the Paterson Institute, all our students benefit from:

- World-class facilities, including deep sequencing, microarrays, mass-spectrometry, advanced imaging, histology, GCLP labs and flow cytometry.
- Core funding by Cancer Research UK, the largest independent cancer research charity in the world.
- A generous stipend of £19,000 per year (tax free).
- Group leaders focused only on research and postgraduate training.
- Working alongside over 400 postdoctoral scientists, clinical fellows, scientific officers, administrative and technical staff, postgraduate research students and visiting fellows.
- Being at the heart of the Manchester Cancer Research Centre, a partnership that brings together the expertise, vision and resources of its founding partners: The University of Manchester, The Christie NHS Foundation Trust and Cancer Research UK – all of which have formidable individual reputations in the fields of cancer treatment and basic and clinical research.

Cancer research in Manchester was ranked by the recent government Research Assessment Exercise (RAE 2008) as the best in the UK. We are committed to training the next generation of cancer research scientists, helping launch careers in basic, translational and clinical cancer research. Postgraduate students enjoy a supportive environment, a challenging project and, together with tailored training in transferable and generic skills, the opportunity to develop as independent scientists with excellent career prospects.

Cancer Research UK studentships are 4 years and include stipend and full University tuition fees (home or overseas) for the duration. Students from within the UK, the EU and internationally are welcome to apply.

Informal enquiries should be addressed to Dr Ian Waddell, the Postgraduate Tutor at: pgt@cruk.manchester.ac.uk.

The deadline for receipt of applications is Friday 29 November 2013 – applications received after this date will not be considered. If you are successfully shortlisted, interviews will be held on 6 & 7 January 2014. Further dates may be added if required.

To make your application, full project details, entry criteria and to find out more about our research, please visit our website: www.cruk.manchester.ac.uk.

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PAUL MCDEVITT

AMERICAN fondness for guns never ceases to amaze. Barry Cash alerts us to a report in *USA Today* at bit.ly/gunsfortheblind stating that blind people in the state of Iowa are being granted permits that allow them to purchase guns and carry them in public.

The report explains: "State law does not allow sheriffs to deny an Iowan the right to carry a weapon based on physical ability."

According to the article, officials in Iowa's Polk County say they have already issued weapons permits "to at least three people who can't legally drive and were unable to read the application forms or had difficulty doing so because of visual impairments".

"No one [in Iowa] questions the legality of the permits," *USA Today* says, "but some officials worry about public safety." Indeed.

Meanwhile, officials in Deer Trail, Colorado, have received 983 applications, each with a cheque worth $25, for a licence to shoot down any government drones that fly over the town.

No such licences exist at present, but thanks to a Deer Trail citizen's initiative, a citywide referendum on the idea is to take place on 8 October. Enthusiastic would-be drone hunters are putting in their orders early – see bit.ly/droneshooters.

READING in the London *Daily Telegraph* about recent attempts to control the weather using high-powered lasers, Neill Jones says he was struck by how scientists sometimes try experiments that are obviously doomed to fail.

Previous unsuccessful attempts include the US seeding clouds with silver iodide in the 1960s to weaken hurricanes, and the Soviet Union trying to induce rainfall around Chernobyl to prevent the spread of radioactive fallout. These, Neill thinks, are reasonable enough.

However, according to the *Telegraph*, "More recently, the Russian air force has also been reported to have used bags of cement to seed clouds." Neill feels sorry for the people living underneath that experiment.

According to the *Hobart Mercury*, David Clark tells us, a meeting about fracking in Oatlands, Tasmania, was addressed by Monash University groundwater specialist Dr Gavin Mudd

FEEDBACK'S eye was caught recently by a report in the *Süddeutsche Zeitung* that fluoride compounds exported from Germany to Syria were declared as being destined for toothpaste manufacture – not for chemical weapons, oh no. It was the amount that struck us: "more than 97 tonnes" of various fluoride compounds during 2005 and 2006.

We reached for a calculator and headed for the bathroom. Its cabinet reveals toothpastes with fluoride doses of 1450 and 1100 parts per million by weight. We don't have a breakdown of the exact quantities of the different compounds that were shipped from Germany, but the one containing least fluoride is sodium fluoride at 45 per cent fluoride by weight – so in round numbers we can say that the compounds contained around 25 tonnes of fluoride per year (roughly half of 45 per cent of 97 tonnes). That's enough for 25,000 tonnes of toothpaste.

The CIA estimates Syria's population at 22.5 million and does not report toothpaste as one of the country's major exports. So every child, woman and man in the country could be supplied with 1.1 kilograms of fluoride-containing toothpaste per year; maybe more.

Surely Germany's reputedly meticulous bureaucrats could have spotted how unlikely these amounts were?

THE WoodMiser that Jenny and Henry Tarbatt noticed advertised in their Expert Verdict catalogue ("always good for the odd chortle") consists of a metal mesh that is placed under firewood to supposedly increase its burning time by 33 per cent.

"How does this amazing metal mesh work? By spreading the heat and slowing the air across the base of your fire to improve heat generation efficiency," the advert tells us. "The science? Not quite so simple, but basically the mesh is created by fast-cooling special metal fibres at a staggering rate of 1 million degrees per second."

"We are... staggered," say Jenny and Henry.

SCIENTIFIC paper title of the week comes to us courtesy of a colleague who assures us, "I kid you not." He came across the paper in the journal *Foods* (vol 2, p 393). It is entitled: "Magnetic Resonance Imaging: A Tool for Pork Pie Development."

AUCTION site ebay now lists its fees to the nearest 0.000001 penny. Martyn Ellis sends a screenshot showing a charge of £1.878252 to include a photo of the item he's selling.

FINALLY, Jeff Dickens was provoked by our proposition that a written notice apparently intended to be read by rabbits and hares – "Rabbits and Hares this gate must be kept shut" – indicates that these furry animals must be very intelligent (7 September).

Jeff responds with scorn: "These rabbits and hares can't be that intelligent if they need signs to remind them not to leave gates open in sheep country. Tsk!"

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

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Soft focus

Here's something for all rich tea fans who like to dunk the biscuit in their tea. Try dunking it first in hot, black, unsugared tea. When you bite into the dunked portion, you will notice that although wet on the outside, it is just as hard on the inside as if you had never dunked it. Now add milk to the tea, stir, and dunk another biscuit into it. Amazingly, the dunked portion is moist and soft right through. So why the difference?

■ The secret is in the milk's butterfat and how this interacts with the biscuit's ingredients and structure to help the tea soak into it.

Rich tea biscuits contain both water-soluble ingredients, notably sugars (around 18 per cent by weight), and hydrophobic substances like vegetable oil (around 14 per cent). The bulk of the biscuit is wheat flour (around 45 per cent), itself predominantly insoluble but water-loving starch. The vegetable oil helps blend and bind the other ingredients into a workable dough, and acts as a shortening to make it crumbly.

Other ingredients include glucose-fructose syrup, barley malt extract, raising agents and salt, though their proportions vary between manufacturers. The malt is what gives rich tea its distinctive flavour, while the syrup fine-tunes the sweetness. The raising agents release carbon dioxide that permeates the dough during baking, rendering the biscuit porous – and accordingly lighter.

Both black and milky teas are drawn into the pores by capillary action. However, because black tea is primarily water, its progress is hindered to some degree by the oil lining the pores, so it fails to reach the inside of the biscuit during a brief dunking. At the same time, the sugar and salt in the biscuit draw the tea out of the pores, reducing the amount of liquid that can seep deeper. The sugar also dissolves, softening the biscuit's moist outside.

Milk, however, contains globules of liquid butterfat suspended in an aqueous solution of mainly lactose. The fat-loving butterfat globules enable the milk to seep more readily through the biscuit's pores, allowing it to reach, and soften, the biscuit's centre. Of course, if dunking lasted long enough, black tea would also soften the biscuit right through.

"Black tea is primarily water and its progress into a biscuit's centre is hindered by oil in the biscuit"

If you like your tea milky, yet are anxious not to lose your biscuit's inner crunch, you could try replacing full-fat milk with skimmed, or perhaps semi-skimmed. But if that doesn't do the trick, and you happen to like black coffee, then that might make a refreshing alternative.

Enjoy your tea break.

Len Winokur
Leeds, UK

Big blue

Why do blue whales need to be so big when they only eat plankton?

■ Blue whales need to be so big precisely because they eat tiny food, specifically krill, small crustaceans that feed on plankton.

Krill defend themselves against smaller predators by forming very dense shoals that confuse attackers. Blue whales get around this by swimming very fast at the shoal with their mouth wide open, often from below, and engulfing as much as they can. Their pleated throat can expand enormously to take in as much of a shoal as possible. The whales then strain out the krill by forcing the water out through the baleen plates in their mouth.

Because each attack uses up a lot of energy, this feeding strategy – called lunge feeding – only works if the animal can take in enough krill to more than repay the cost, so the whale needs to be huge to use it effectively.

Peter Wright
Polegate, East Sussex, UK

■ One struggle for mammals that live in a cold ocean is to maintain their body temperature. Besides having a thick layer of blubber as insulation, another strategy is to be as large as possible, because this minimises their surface area-to-mass ratio. In other words, there is less surface area through which to lose heat per unit of body weight. Young whale calves don't have this benefit, which is one reason why many whale species migrate to warmer waters to give birth. The calves then have the chance to fatten up before they venture to colder waters.

The upper limit on body size is determined by the skeletal structure needed to support the body. For land mammals this is a more serious limit because they don't have the buoyancy of the water to help support their weight. That is why land mammals can't grow as large as whales.

Simon Iveson
University of Newcastle Callaghan, New South Wales, Australia

This week's question

DUNG-HO INSECTS

In a boggy field in Dorset, we saw these butterflies apparently feeding on dung (see photo). What is going on?

Margaret Kettlewell
Bournemouth, Dorset, UK

The writers of answers published in the magazine will receive a cheque for £25 (or US$ equivalent). Answers should be concise. We reserve the right to edit items for clarity and style. Include a daytime telephone number and email address if you have one. We are pleased to acknowledge financial support from Statoil in producing The Last Word. New Scientist retains total editorial control over the content.

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3D PRINTING IS CHANGING MODERN MEDICINE

FROM 3D PRINTED ORGANS TO MEDICINES AND PROSTHETICS, WE ARE AT THE EDGE OF A REVOLUTION.

The 3D Printshow Hospital will throw its doors open to the public, showcasing work by the brightest minds in this field. From the cancer patient with a new face to the 'Bionic Ear' that could allow humans to hear radio signals, you won't believe the breakthroughs that are already being made!

MEDICAL CONTENT
3D PRINTED ORGANS
TISSUE PRINTING
OCULAR PROSTHESIS
SOFT TISSUE PROSTHESIS
STEM CELL PRINTING
DIGITAL DENTISTRY
EDUCATION & DEVELOPMENT

Michael mc Alpine's 'Bionic Ear'
Mc Alpine Research Group, Princeton University

/3dprintshow